Delaware Department of Agriculture

2011 Specialty Crop Block Grant Program- Farm Bill

Final Revised Report – April 2015

Agreement Number 12-25-B-1219

Serving Agriculture and Protecting Consumers

CONTACT

Jo-Ann Walston
Marketing Specialist II
Phone: 302-698-4592
E-mail: JoAnn.Walston@state.de.us

Below are the Final Reports for the 8 projects that are funded under this Specialty Crop Block Grant.

Project Title: Determining the Ideal Irrigation Strategy to Maximize Lima Bean Yield and Quality

Abstract: Research will be performed to determine the ideal irrigation management strategy for lima beans. An automatic irrigation control system will be utilized to schedule irrigation based on actual soil moisture levels. Yield and quality differences will be compared across 4 irrigation treatments and the economics of each intensity level will be determined and shared with producers.

Project Summary: This project will develop an accurate determination of the water requirements for lima beans, the major processing vegetable crop grown in Delaware and provide much needed data on how to further increase irrigation efficiency. Of the 41,000 acres of vegetables harvested in 2010, 13,000 acres were planted in lima beans, with approximately 60% of those acres under irrigation.

Maintaining optimum soil moisture for maximum crop production is complicated. Crops pull water from the soil profile at different rates from day to day and throughout the day. Over the season changes take place in the root zone as the crop grows and crop water use increases. These changes tend to create curve that represents an increase in daily crop water use as the plant grows and enters the reproductive phases followed by a gradual decline as the crop matures. In addition to effective rooting depth, optimum soil moisture levels will also depend on soil physical characteristics such as soil texture and bulk density.

Ritter et al. (1985) estimated crop water use curves for lima beans in 1985, but these published values were not validated with field measurements. Proper irrigation rates can dramatically increase yield, reduce weed and disease problems, and increase nutrient management and water usage efficiencies. With nearly 1/3 of our vegetable acreage planted to lima beans it is critical that we determine the ideal irrigation management strategy using modern soil moisture monitoring technology and current cultural practices.

Significant improvements in the technology of soil moisture monitoring over the past 25 years will result in much more accurate monitoring of the soil moisture profile when compared to the weekly measurements made in previous studies. By using automatic logging soil moisture probes on a 30 minute logging interval, combined with tipping bucket rain gauges and highly accurate weather station data, a much more accurate picture of the changes in crop water use can be determined.

Many of the cultural practices in vegetable production have changed since the 1985 Ritter report and these changes may affect water requirements.

Delaware vegetable growers face a very competitive national market, while growing their crops in a climate that may be among the most variable and unpredictable in the nation. Giving our growers the ability to irrigate more efficiently and effectively would allow them a better competitive edge and updated crop water use curves for lima beans, the largest acreage vegetable crop in DE, is a critical component to this end.

Project Approach: Irrigation research for baby lima beans will be performed on the University of Delaware, Research and Education Center farm in Georgetown. The field trials will have 4 replications of two varieties of baby limas (one less stress tolerant and one more stress tolerant) with four irrigation treatments (8 plots total per replication). Plots will be 2 rows, 25' in length. Irrigation will be provided by 2 lines of low flow (0.22 gpm/100') drip tape per plot.

Irrigation treatments will consist of:
Treatment 1 – No Irrigation
Treatment 2 – Irrigation will be triggered when the plant available water (PAW) reaches 50% of capacity throughout all crop stages; irrigation will be interrupted when the soil reaches field capacity (100% available water).
Treatment 3 – Irrigation will be triggered when the PAW reaches 35% of capacity throughout all crop stages; irrigation will be interrupted when the soil reaches field capacity (100% available water).
Treatment 4 – Irrigation will be triggered during vegetative growth stages at 35% of PAW followed by a 50% PAW trigger during reproduction.

Decagon 5TE volumetric soil moisture sensors (later replaced with Watermark sensors) will be placed at 6", 12" and 18" depths within each plot and will be hard wired to a Campbell CR 1000 data logger. The data logger will collect and record the real time soil moisture content every ½ hour. The data logger control ports will energize a 24VAC solenoid valve to initiate irrigation whenever the measured soil moisture levels are below the set point. The irrigation drip lines, soil moisture sensors and irrigation controls will be installed by James Adkins and his field technician. He will also manage the irrigation treatments.

Each plot will be evaluated for plant effects, harvestable yield, and quality. Plots will be harvested as close to ten percent dry pods as possible. Plants will be cut off at soil level and weighed for fresh weights. To determine maturity at harvest, pods will be stripped from five harvested plants from each plot and counted as full, flat or dry. The plants and pulled pods will be fed into a stationary FMC viner to shell. After cleaning of any trash, shelled beans will be weighed to determine yield. Plant stress measurements such as canopy temperature or spectral reflectance will also be collected at points throughout the growth cycle. All harvest data collection will be performed by Gordon Johnson, Emmalea Ernest and vegetable program field crew. Presentations will be made by James Adkins and Gordon Johnson at the 2014 & 2015 Delaware Ag Week to present the results of this 3 year study.

Activities Performed:
2012
The research plots were planted in June according to the standard Delaware baby lima cultural practices. The crop emerged evenly with adequate stand to provide a reasonable data collection. Unfortunately, the well needed for this project faced multiple installation delays, preventing the installation of the drip tape and beginning of the irrigation treatments until August 2^{nd}. By this

point, the hot and dry summer combined with the very light soil in the plots and lack of irrigation presented significant moisture stress to the crop.

Once installed, the irrigation was run in the various treatments daily for nearly 2 weeks before rainfall refilled the soil profile. Plot irrigation was triggered at the 4 moisture levels as planned however; due to limited pumping capacities the moisture targets were not adequately maintained. As a result, the harvested yields were most affected by the replication number (field location) rather than irrigation treatment. The yield results reflected the fact that rep 4 was located on the lowest, highest nature moisture availability, which returned the highest average yields. Likewise rep 3 showed the poorest yields as it was located in the highest, sandy field location. Overall, there was no statistical yield difference between the treatments although the wetter treatments had more overall water application.

2013

Starting in late May the 8 mil drip irrigation tape was laid with a 3 row RainFlo tape installation machine at an average depth of 4". The research plots were planted in on May 31st, according to the standard Delaware baby lima cultural practices. The crop received 2.6" of rain 3 days after planting and another 2.5" 5 days later. The successive rain events resulted in a poor and uneven stand that was inadequate for generating any data.

The crop was replanted in June 25th, the soil moisture sensors were installed and the plots received another 1.4" of rainfall within 2 days resulting in a marginal stand. It was decided that despite the delayed and uneven emergence, to wait and evaluate the stand in 2 weeks as the field was too wet to replant anyway. After 2 weeks of continued rain totaling over 5.5", the stand was determined to be yield limiting and unusable. By July 22nd the field had dried sufficiently for a 3rd planting however it was too late in the season for lima beans to produce a crop before a freeze. At this point the project was abandoned for the year, the soil moisture sensors were removed, and drip tape was pulled.

2014

Based on the failure to establish an adequate crop in the 2012 and 2013 season to due to unreliable irrigation water availability and poor drainage, the research site was moved to the UD Warrington Irrigation Research Farm. The drip tape was installed and the lima beans were planted on June 3. Two varieties (C-Elite and Cypress) were planted at a population of 4 seeds per foot with a Monosem vacuum plot planter. The soil moisture equipment and irrigation hookup was installed the following week and tested. The crop emerged on June 12th and maintained an excellent stand until July 11th at which point nearly the entire plot was devoured by deer in one night. The plots were replanted on July 17th with an assumed risk that frost could prevent harvest. Adequate rains throughout August and September minimized the need for irrigation and thus there were no differences between treatments. The hard frost received on November 8th killed the plots and any chances of measuring yield data.

Goals and Outcomes: The repeated failures to achieve and maintain an even and representative lima bean stand prevented any of the planned goals from being achieved. Since no measurable yield data was able to be collected, none of the perceived benefits of improved yields and nutrient management could be quantified and therefore none of the presentations of results were conducted. The all-encompassing goal of developing a water use curve for lima beans was overly optimistic in a region of high rainfall without employing a rain structure to prevent plot contamination from rain. As stated, no presentations were made on this project as no data was generated to present. As a result none of the planned surveys, fact sheets, or water use curves could be generated.

Beneficiaries: Absolutely no one benefited from this project due to the inability to establish enough of a crop to measure. The only potential benefit was the development of a reliable system to automate irrigation for future vegetable crop irrigation studies. As stated above, no presentations were made on this project as no data was generated to present and therefore the beneficiaries were zero.

Lessons Learned: While no lessons were learned that would benefit farmers in the region, several concepts that will be beneficial for future research were learned. The development of an automated system for triggering irrigations for replicated research and the need for deer fencing when performing lima bean research are foremost. Additionally, we learned that when performing short term research aimed at developing water use curves, all crops should be planted under some type of rain structure to prevent precipitation from skewing the treatments and plot results. All follow-up questions were addressed in the original report.

Funding Expended to Date: $7,929.82

Project Contact: James Adkins, University of Delaware Carvel REC
16483 County Seat Highway, Georgetown, DE 19947, 302-856-7303, adkins@udel.edu

Project Title: Herbicide Programs for Sweet Corn Without Limiting Vegetable Crop Rotation

Project Summary: Weed control in sweet corn is challenging for a number of reasons. Finding a balance between weed control, crop safety, and rotational flexibility is difficult. Unfortunately many sweet corn growers have had to choose either good weed control or rotational flexibility. Two herbicides (Impact and Laudis) were labeled for use in sweet corn just prior to initiating this project. Both exhibit excellent crop safety, outstanding weed control, and greater flexibility for vegetable rotations. The Impact label provides “rotational crop guidelines” rather than “rotational restrictions”. In fact, the Impact label states “**planting earlier than the recommended interval may result in crop injury**” but does not prohibit earlier planting. This project will examine a range of vegetables commonly planted after a sweet corn crop and assess the rotational crop safety of Impact and Laudis. The project will focus on effective herbicides that allow vegetable crops to be planted at acceptable intervals and still observe Good Agricultural Practices.

Growers are looking for safe, effective herbicides that will allow them to maintain a flexible crop rotation. The wording on the Impact label allows growers to plant with shorter time intervals than those listed on the label, provided growers are comfortable with the risk. We intend to provide local information that will allow growers to make more informed decisions about the level of risk of replanting. Furthermore, the results can be used immediately by growers; no further labeling changes or regulatory changes need to be implemented to plant at these shorter intervals.

Potential Impact: In the 2007 Agricultural census, Delaware reported 79 farms growing sweet corn, totaling just over 9,000 acres. Sweet corn accounts for approximately 20% of all the vegetable acreage in Delaware. This research will impact those growers who double crop a second vegetable after the sweet corn harvest as well as those fields that will be planted to vegetables the year following sweet corn.

Greenhouse research: Laudis and Impact were evaluated for crop safety for a range vegetable crops that could be planted after sweet corn. These included snap bean, lima bean, pickling cucumbers, and spinach. The vegetables were treated with a range of herbicide rates to determine differences in response to Impact and Laudis. Two varieties of each vegetable were used to determine if there are differences in varietal response to either herbicide. Visual injury was collected at weekly intervals and plant biomass collected at 3 weeks after planting. All treatments were replicated three times and the study was repeated. Laudis caused significant amount of injury for snap bean, spinach and to a lesser extent lima beans and cucumbers.

				Snap	bean			Lima		Cucu	mber
Herbicide	Rate		Caprice	Dart	Envy	Slederpack		bean		Expedition	Vlaspik
Impact	0.1X		0	8.5	0.7	0		0		0.1	0
Laudis	0.1X		11.3	17.7	21.7	23.2		11.7		8.7	--

Field research: Most of the trials were conducted at the UD Research and Education Center. Laudis was not included in the field trial due to the level of injury observed in the greenhouse. Experimental site was conventionally tilled to coincide with planting dates for early planted sweet corn. No sweet corn was planted to minimize influence of crop residue on establishment of rotational vegetables. Impact was sprayed at 2X and 4X the labeled rate. Treatments are listed in Table 1. Herbicide treatments were applied at four weeks after tillage, corresponding with typical timing for postemergence herbicides. Glyphosate and paraquat were used to prevent weeds from establishing prior to planting rotational vegetables. Approximately 70 days after initial tillage, half the plots were field cultivated and the other half no soil disturbance. ‘Cypress’ lima bean, ‘Slenderpack’ and ‘Envy’ snap bean, and ‘Expedition’ pickling cucumbers were planted. Varieties were selected based on both sensitivity in the greenhouse and varieties commonly planted in Delaware.

In a separate trial, focusing on fall planted vegetables, the herbicide treatments were field cultivated in early August and fall-seeded vegetables were planted. These included ‘Bloomsdale’ and ‘Persius’ spinach, ‘Dwarf Siberian’ kale, ‘Champion’ collards, and ‘Seven Top’ turnips.

For both trials, visual ratings for crop response to Impact were taken at regular intervals starting at 7 days after emergence. Summer vegetable plots were hand harvested as individual crops matured. Fall vegetables were not harvested.

Table 1. **Evaluating Rotational Vegetable Crop Sensitivity to Impact in year 1**

Herbicide treatment		Rate	Lima Cypress Injury % 1 WAE	Snap Envy Injury % 1 WAE	Snap Slendrpk Injury % 1 WAE	Cucumber Expeditn Injury % 1 WAE	Snap Envy Injury % 2 WAE	Snap Slendrpk Injury % 2 WAE	Cucumber Expeditn Injury % 2 WAE	Lima Cypress Injury % 3 WAE
Untreated Check			0	0	0	0	0	0	0	0
Impact	1	fl oz/A	2.8	13.3*	5.3	0.8	20.3*	5.2	2.5	1.7
Impact	2	fl oz/A	5.7*	30.7*	15.5*	0	35.5*	17.8*	1.7	0.2
Impact	4	fl oz/A	13.8*	53.3*	35.3*	6.5*	64.7*	46.3*	9.7*	4.7
Impact+Atrz[a]	1	fl oz/A	2.3	15.5*	9.5*	0	16.8*	6.5	0	0
Impact+Atrz[a]	2	fl oz/A	7.2*	32.5*	17.7*	0	35.8*	14.2*	1.3	3.7
		LSD	4.3	10.7	8.6	2.4	14.7	10.8	3.6	NS

[a]Atrazine rate was 0.5 lbs/A.
WAE= weeks after emergence
*= treatments are significantly different than untreated check.

Table 2. **Evaluating Rotational Summer Vegetable Crop Sensitivity to Impact in year 2**

Herbicide Treatment		Rate	Lima Cypress Injury % 1 WAE	Snap Envy Injury % 1 WAE	Snap Slendrpk Injury % 1 WAE	Cucumber Expeditn Injury % 1 WAE
Untreated Check			0	0	0	0
Impact	1	fl oz/A	9*	12*	11*	4
Impact	2	fl oz/A	9*	14*	12*	10*
Impact	4	fl oz/A	5	20*	14*	9*
Impact+Atrz[a]	1	fl oz/A	4	9	10*	3
Impact+Atrz[a]	2	fl oz/A	6	10*	9*	5
		LSD	6	5	3	6

[a]Atrazine rate was 0.5 lbs/A.
WAE= weeks after emergence
*= treatments are significantly different than untreated check.

Table 3. **Crop Yield When Planted After Sweet Corn Treated with Impact in year 1**

Herbicide Treatment		Rate	Cucumber Expeditn Yield lbs/10ft	Snap Envy Yield Lbs	Snap Slendrpk Yield Lbs	Lima Cypress Yield grams
Untreated Check			2.8	1103.5	853.8	0.21717
Impact	1	fl oz/A	3.02	786.4*	1033.8	0.22983
Impact	2	fl oz/A	3.26	160.3*	755	0.23933
Impact	4	fl oz/A	4.127	7*	269.5*	0.23417
Impact+Atrz[a]	1	fl oz/A	3.35	867.7	845.6	0.14033
Impact+Atrz[a]	2	fl oz/A	4.073	225.48	766.7	0.12248
		LSD	NS	293	286	NS

[a]Atrazine rate was 0.5 lbs/A.
WAE= weeks after emergence
*= treatments are significantly different than untreated check.

Table 4. **Summer Crop Yield When Planted After Sweet Corn Treated with Impact in year 2**

Herbicide Treatment	Rate		Cucumber Expeditn Yield lbs/10’	Snap Envy Yield lbs/25’	Snap Slendrpk Yield lbs/25’	Lima Cypress Yield lbs/25’
Untreated Check			2.473	9.953	6.693	0.507
Impact	1	fl oz/A	3.127	4.587	5.473	0.520
Impact	2	fl oz/A	2.567	3.613	5.369	0.560
Impact	4	fl oz/A	4.173*	2.200*	8.138	1.053*
Impact+Atrz[a]	1	fl oz/A	3.140	7.733	7.702	0.620
Impact+Atrz[a]	2	fl oz/A	3.720	7.887	8.063	0.467
		LSD	0.994	4.172	NS	0.304

[a]Atrazine rate was 0.5 lbs/A.
WAE= weeks after emergence
*= treatments are significantly different than untreated check.

Table 5. **Evaluating Fall-Planted Rotational Vegetable Crops Sensitivity to Impact in year 2**

Herbicide Treatment	Rate		Spinach* Injury % 4 WAP	Kale Injury % 4 WAP	Collards Injury % 4 WAP	Turnips Injury % 4 WAP	Kale Injury % 6 WAP	Collards Injury % 6 WAP	Turnips Injury % 6 WAP
Untreated Check			0	0	0	0	0	0	0
Impact	1	fl oz/A	0	0	0	0	7	3	7
Impact	2	fl oz/A	0	10	8	10	9	5	12
Impact	4	fl oz/A	0	7	2	7	12	6	12
Impact+Atrz[a]	1	fl oz/A	13	13	9	10	7	12	15
Impact+Atrz[a]	2	fl oz/A	8	10	12	8	20	13	13
	LSD		NS	NS	NS	NS	NS	NS	NS

* The spinach stand was poor and only one injury rating was taken.

Lima beans and pickling cucumber exhibited very little injury from Impact applications and were able to grow out of any injury quite rapidly. No yield loss was detected with lima beans, and only reduced yield with pickling cucumbers was observe in the second year at 4X rate of Impact. Snap beans were consistently injured by Impact and yield was reduced with the variety Envy.

Additional field trial. In 2014, Impact (at 0.75 and 2.0 fl oz/A) plus atrazine (0.5 lbs ai/A) was applied to commercial field of sweet corn. After sweet corn harvest, the field was moldboard plowed and spinach was planted. No injury was observed on the spinach and spinach yields were not affected by either rate of Impact.

Problems and Delays: While the site was irrigated, it was difficult to maintain a consistent irrigation schedule. As a result, yields were lower than expected. However, this study was looking at differences between treatments and irrigation did not impact the final conclusions.

Goals and Outcomes Achieved: Based on the research to date, we have achieved a better understanding of double-cropping vegetables after sweet corn, without sacrificing weed control in sweet corn. Impact provided a high level of weed control (data not presented) and minimal injury to lima beans and pickling cucumbers. Snap beans did not exhibit the same level of crop safety and we have cautioned against planting snap beans immediately after sweet corn treated with Impact. This information has been presented at the Processing Crops Session at the Delaware Ag Week in 2011, 2012, and 2013. It has been addressed in Weekly Crop Update Articles (weekly newsletter that gets distributed among farmers, crop consultants and agri-businesses) in the past two years. Results have been incorporated into the Mid-Atlantic Vegetable Production Guide. Furthermore, I have had one-on-one conversations with fieldmen from the various processing companies about use of Impact in sweet corn, focusing on sweet corn safety, weed control, and issues with vegetable rotations. Anecdotal evidence is that Impact has become a widely used product for sweet corn without limiting crop rotation. Quantifying the acreage using this approach is beyond the scope of this proposal, and somewhat premature since 2014 was the first field season after 2-years of data were summarized.

Proposal revisions in 2013 included a lima bean meeting for the fall of 2014. This meeting has been planned for mid-December, and organizers selected a date that I have a conflict. However, there is a round-table discussion planned during DE AG Week organized by Gordon Johnson to address topics of specific concern to processors. This research and future research needs will be discussed.

In the original proposal, use of Laudis was discussed as a potential product for use with double cropped vegetables. However, based on extensive greenhouse testing, it was not included in the field trials due to level of injury observed.

Results do not address potential rotational issues with peas, watermelon, cantaloupes, or solanaceous crops such as peppers, tomatoes, and potatoes. Additional research is needed to provide guidance for growers wishing to use these rotations.

One advantage for vegetable growers is potential to use a different herbicide site of action (SOA) with sweet corn. This herbicide SOA is unique to sweet corn (or field corn) and provides an opportunity to address herbicide-resistance through rotations.

Beneficiaries: As mentioned above, the beneficiaries include farmers, processors' field men, and agrichemical business. While the focus was on crops grown after sweet corn (lima beans, snap bean, cucumbers, and fall vegetables) it has helped a broader range of farmers as well, notably growers planting soybeans after sweet corn. It is difficult to quantify the impact of this research in terms of farms or farmers. In the 2007 Agricultural census, Delaware reported 79 farms growing sweet corn, totaling just over 9,000 acres.

Lessons Learned: This project began when we started to receive more reports of Palmer amaranth and Texas panicum infested fields. Both of these species have been designated as noxious weeds in DE due to their competitiveness with crops and difficulty in controlling. Based on trials, funded through other sources, we have observed very good control of Palmer amaranth with Impact and commercially acceptable control of Texas panicum. The control of these noxious weed species have also heighten farmers and agribusiness interest in usage of Impact.

One unexpected outcome is this project coincided with a renewed interest in cover crops. Our experience from this work has given us a "leg up" on addressing herbicide carryover concerns to brassica cover crops. Since we had looked at some brassica species in the current trial we knew what crops might be most sensitive to include in these trials.

Contact Person: Mark VanGessel, Office Phone: 302/856-7303 ex 510; email: mjv@udel.edu

Project Title: Variety Testing in Advance of Release of New Lima Bean Cultivars and Continued Lima Bean Breeding and Selection

Project Summary: Lima beans are Delaware's most widely planted vegetable crop and are important for the state's processing vegetable growers. The majority of the lima bean acreage is green baby limas grown for processing (13,000 acres planted in 2012). Fordhook lima beans are presently grown in Delaware for fresh market. There is a continued interest in Fordhooks from the regional vegetable processors and one processor is contracting several hundred acres of Fordhooks in 2010; however the available Fordhook varieties produce very erratic yields in our climate. Both Fordhook and baby limas

A lima bean breeding program at University of Delaware was initiated in 2004 with the goal of addressing several of the production problems related to baby and Fordhook lima beans. Advanced lines of baby lima beans from this program have been tested in replicated trials annually since 2008. Lima varieties from the UD lima breeding program have produced consistent high yields in these trials compared to the currently grown commercial varieties. Fordhook lines from the breeding program have been tested annually in replicated trials since 2010 and have performed well.

The purpose of this project was continued support of the breeding program; support of field-scale trials of UD bred green baby and Fordhook breeding lines as well as support of the earlier stages of the breeding process, which put new and better material into the pipeline for eventual testing and release.

The UD lima bean breeding program was supported by a past Specialty Crop Block Grant. The past grant supported the initial crossing, selection and small scale trialing of lines from the breeding program. The purpose of this grant is to support the field-scale trial of UD bred green baby and Fordhook breeding lines as well as to continue to support the earlier stages of the breeding process, which put new and better material into the pipeline for eventual testing and release.

Project Approach: Breeding Program Activities
Each year of the grant the following activities were carried out as a part of the breeding program: New crosses were made in the greenhouse in November, December and January. The resulting F_1 plants were grown in the greenhouse in March through June to produce seed for field selection. Seed of F_2, F_4 and F_6 generation lines were planted in the field in June and selections were made from these lines in October. Selections from the F_2 and F_4 generations were grown in the greenhouse in for either fall (October-February) or spring (March-June) grow-out to produce seed for the next year's June field planting. Seed of the F_6 generation was grown in the greenhouse and sent to a contracted winter nursery in Puerto Rico to produce enough seed for yield testing in a replicated trial in Delaware the following year. The table below summarizes the number of lines developed and advanced through the breeding program in the years of this grant for Fordhook and baby limas.

Irrigated Baby Limas	**2012**	**2013**	**2014**
New Crosses/F_2 Lines	43	31	36

F_4 Lines	81	116	135
F_6 Lines	70	110	120
F_8 Lines for Yield Testing	30	33	39
Fordhook Limas			
New Crosses/F_2 Lines	13	15	4
F_4 Lines	55	55	29
F_6 Lines	5	5	65
F_8 Lines for Yield Testing	22	1	21

Testing of Advanced Breeding Lines at the University of Delaware Research Farm, Georgetown

In each year of this grant replicated yield trials were performed at University of Delaware's research farm in Georgetown, DE. The following table summarizes the number of advanced lines from the UD lima breeding program tested in trials at the research farm from 2012-2014.

Trial Description	**Number of UD Lines Tested**		
	2012	**2103**	**2014**
Irrigated Baby Lima Trial	26	38	45
High Stress Baby Lima Trial	21	30	31
Fordhook Trial (Irrigated)	19	14	18

Detailed reports on these trials are posted online at http://extension.udel.edu/ag/vegetable-fruit-resources/vegetable-small-fruits-program/variety-trial-results/.

Other Trials and Assessment of Advanced Breeding Lines

Quality Assessment of Advanced Breeding Lines

UD Fordhook and baby lima breeding lines with green or light green seed were evaluated for freezing quality by a panel of eight fieldmen, and processing and preprocessing quality experts from the four regional lima bean processors on December 11, 2012. Blanched and frozen samples from the 2012 variety trials were used. The results of this evaluation are reported in the 2012 Lima Bean Variety Trial report (http://extension.udel.edu/ag/files/2012/03/lima2012.pdf). Samples from the 2014 trials have been blanched and frozen with the expectation of evaluating them in a similar manner in December, 2014.

Field Trials of Advanced Breeding Lines with Growers and Processors

In 2012 eight lines were tested in a field scale trial against the standard variety C-elite Select. This trial was planted with a grower cooperator near Milton, Delaware and was harvested by machine. The results of this trial are in the 2012 Lima Bean Variety Trial report (http://extension.udel.edu/ag/files/2012/03/lima2012.pdf)

In 2013 two advanced baby lima lines (DE0407905 and DE0501801A) were tested in field-scale strip trials with the cooperation of growers and regional processors, Seabrook Brothers & Sons and J.G. Townsend Frozen Foods. The two lines were tested against '184-8'5 in Hurlock, Maryland and against 'Cypress' in Lewes, Delaware.

Plans to do additional field scale testing of lima lines was hampered by difficulties in making arrangements for large scale seed increases needed to produce seed for these trials.

The work described above was carried out by Emmalea Ernest, which assistance from seasonal employees. Grower and industry cooperators were also important contributors as noted.

Goals and Outcomes Achieved: One goal of this project was to identify at least one baby lima bean variety from the UD breeding program that is ready for release as a variety and to begin increasing seed for commercialization. The performance of UD breeding lines with seed quality traits making them of particular interest for commercial release is as follows:

DE0407905 has been tested in trials since 2008 (7 years). Based on those trials planted in the first two weeks of June average maturity is 88 days to harvest (DTH) and average yield is 3967 lbs/A. In comparison to the standard varieties included in all seven trials DE0407905 has a significantly higher yield than Cypress (avg. 3119 lbs/A) and numerically higher but not statistically different yield than C-elite Select (avg. 3929 lbs/A) and 184-85 (avg. 3658 lbs/A). Maturity for DE0407905 is statistically different than all of the standards. It is later than Cypress (avg. 83 days) and earlier than C-elite Select (91 DTH) and 184-85 (90 DTH).

DE0407907 has been tested in trials since 2008 (7 years). Based on those trials planted in the first two weeks of June average maturity is 90 days to harvest (DTH) and average yield is 4006 lbs/A. In comparison to the standard varieties included in all seven trials DE0407907 has a significantly higher yield than Cypress (avg. 3119 lbs/A) and 184-85 (avg. 3658 lbs/A). It has a numerically higher but not statistically different average yield than C-elite Select (avg. 3929 lbs/A). Maturity for DE0407907 is not statistically different than C-elite Select (91 DTH) and 184-85 (90 DTH). It is significantly later than Cypress (avg. 83 days). DE0407907 is resistant to race F of downy mildew, which is the predominant race present at this time. None of the standard varieties are resistant to race F.

Seed of DE0407905 and DE0407907 was sent to Dixon Seed in Glenn, California for larger scale increase in May 2014.

A second goal of this project was to have some Fordhook lines that have undergone several years of replicated yield trials and that are ready for field-scale trials. UD Fordhook lines of particular interest because of yield and quality characteristics are as follows:

DE0600605C has had consistently high yields in the four years it has been trialed. The four year average yield for this line is 4854 lbs/A, or 172% of the yield of Concentrated Fordhook for those same years. DE0600605C was rated unacceptable for commercial production because of its light colored seed by the majority of evaluators in 2012. It has been used as a parent for numerous Fordhook breeding lines that are still in development in the program.

DE0600602B has had consistently high yields in the four years it has been trialed. The four year average yield for this line is 4273 lbs/A, or 151% of the yield of Concentrated Fordhook for those same years. DE0600602B was rated unacceptable for commercial production because of its light colored seed by the majority of evaluators in 2012, but had slightly better acceptability than DE0600605C. It has been used as a parent for numerous Fordhook breeding lines that are still in development in the program.

DE0701301A has been tested for three years and has performed well. The three year average yield for this line is 3907 lbs/A, or 152% of the yield of Concentrated Fordhook for those same years. Yield is not as high or as stable as the DE0600605C, but DE0701301A has commercial quality green seed and was rated acceptable by all of the 2012 evaluators. It also had excellent emergence and final stand in the 2012 and 2013 trials.

Fordhook lines were successfully increased on a small scale in the field in Delaware in 2014 by cutting plants as the reached maturity and placing them under cover as the seed dried. Seed was also sent to a cooperator in Washington for a trial increase under their field conditions. Seed from the Delaware increase will be used for larger trials at the UD research farm or with grower cooperators in 2015.

Investment in the early stages of the breeding program has resulted in many new and exciting breeding lines that were tested for the first time in the 2013 or 2014 trials. Traits of particular interest in these promising lines include superior stress tolerance, early maturity, downy mildew race F resistance, high yield, concentrated pod set, yield stability and commercially acceptable seed quality.

Research results related to this project have been presented to growers, vegetable processors and crop consultants at the following meetings:

- Lima Bean Forum, Georgetown DE, December 11, 2012
- Processing Crops Session of the Fruit and Vegetable Growers Association of Delaware Annual Educational Meeting, Harrington, DE, January 16, 2013
- Mid-Atlantic Crop Management School, Ocean City, MD, November 20, 2013
- Processing Crops Session of the Fruit and Vegetable Growers Association of Delaware Annual Educational Meeting, Harrington, DE, January 15, 2014

Research results related to this project have been presented to Extension workers and agricultural researchers at the following meetings:

- Bean Improvement Cooperative Biennial Meeting, Portland, OR, October 29, 2013
- Mid-Atlantic Vegetable Workers Conference, Newark, DE, November 7, 2013

Beneficiaries: The ultimate beneficiaries of this project are the approximately 80+ farms growing lima bean and four lima processing companies in the Mid-Atlantic region. The value of the 2012 processing lima crop in Delaware was $10 million. The regional growers and processors are anxious for improved varieties with better yield, yield stability, stress tolerance and disease resistance to be released by the UD lima breeding program. Breeding and selection in this region has allowed us to develop varieties that perform better under Mid-Atlantic conditions than varieties selected in the western U.S. where the two commercial seed suppliers producing seed for our region are located. Lima growers and processors from outside of the Mid-Atlantic region are also interested in trialing varieties developed by the UD breeding program.

Lessons Learned: Two significant obstacles were encountered in attempting to attain the goals of this project:

One goal of this project had been to trial varieties with resistance to downy mildew races E & F. At the time the grant was written, I expected to have identified a baby lima breeding line with homozygous resistance to both races E & F of downy mildew in 2011. Based on the past several summers' field results the genes for resistance appear to be in fairly tight repulsion phase linkage. As a consequence, in 2012 we continued to screen breeding lines that are segregating at both these loci in hopes of identifying an E & F resistant line. Several possible resistant lines were identified in summer 2012, but were found to be susceptible to at least one race in greenhouse screening. In 2013 and 2014 we screened only for resistance to race F (since it is the predominate race present). Some advanced lines with race F resistance and other desirable characteristics were identified and downy mildew resistance is being considered as lines are selected for continued testing toward future release. A different breeding approach has been adopted as I continue to work toward the goal of varieties with resistance to both race E and F.

Another challenge was finding satisfactory arrangements for seed increases for Fordhook lima beans and large-scale increases for baby lima beans, which is necessary to conduct large scale field trials or ramp up seed production for commercial release. The company that did our previous large scale increases of baby limas is no longer able to handle this task. I was not able to make other arrangements for large scale seed increase for summer 2013, decided to try another company in summer 2014. Attempts to increase Fordhook breeding lines with a collaborator in California were unsuccessful. In 2014 I sent Fordhook lines to a different collaborator in Washington to try increase there. We also did some small scale increases in the field in Delaware as described above. To facilitate seed increases in Delaware I have purchased, through this grant and structure that will be used as a rain shelter to prevent the spoiling of seed as it dries down in the fall. This structure will be used for full season production of Fordhook seed in 2015.

No income was generated as a part of this project.

Contact Person: Emmalea Ernest, 302-856-7303, emmalea@udel.edu

Project Title: Enhancing Processing Vegetable Production for Growers in Delaware and Processors in the Region

Project Summary: The University of Delaware is the main institution in the Mid-Atlantic region conducting research on processing vegetable crops due to the historically large acreage in the state. The goal of this project was to provide a research base to enhance processing vegetable production in DE. Research was conducted on crop culture for yield and quality improvement and cost reduction in production for major processing crops including lima beans, sweet corn, peas, and snap beans.

This project addressed these areas by providing the necessary applied research base. Crop culture research focused on improving yield and quality of processing crops currently being grown in Delaware and managing those factors limiting yields and quality. Research was conducted on yield stabilization and stress management in lima beans and snap beans, nitrogen management in sweet corn, and compaction mitigation in peas. Cost reduction research for processing vegetables included improved inoculants for lima beans and snap beans; N management in sweet corn; no-till and strip-till for peas, lima beans, snap beans, and sweet corn; and re-growth cropping of lima beans.

There are 31,000 acres of processing vegetables grown in Delaware with a value of $20 million dollars. The majority of processing acreage is in baby lima beans, sweet corn, green peas, snap beans and pickling cucumbers. There are over 100 farms in Delaware that contract with regional processors and more than 60 growers on the nearby Eastern Shore of Maryland that receive processing crop information from the University of Delaware vegetable research program. The UD vegetable research program interacts with 7 regional processors that source vegetables from Delaware. Maintenance of current acreage is critical for processor retention. Improved productivity and yield stability is sought by processors to reduce sourcing costs and costs associated with plant scheduling. This research was aimed at improving supplies from a yield stability and quality perspective for processors, reducing costs for processors and growers, and improving profitability of both processors and growers.

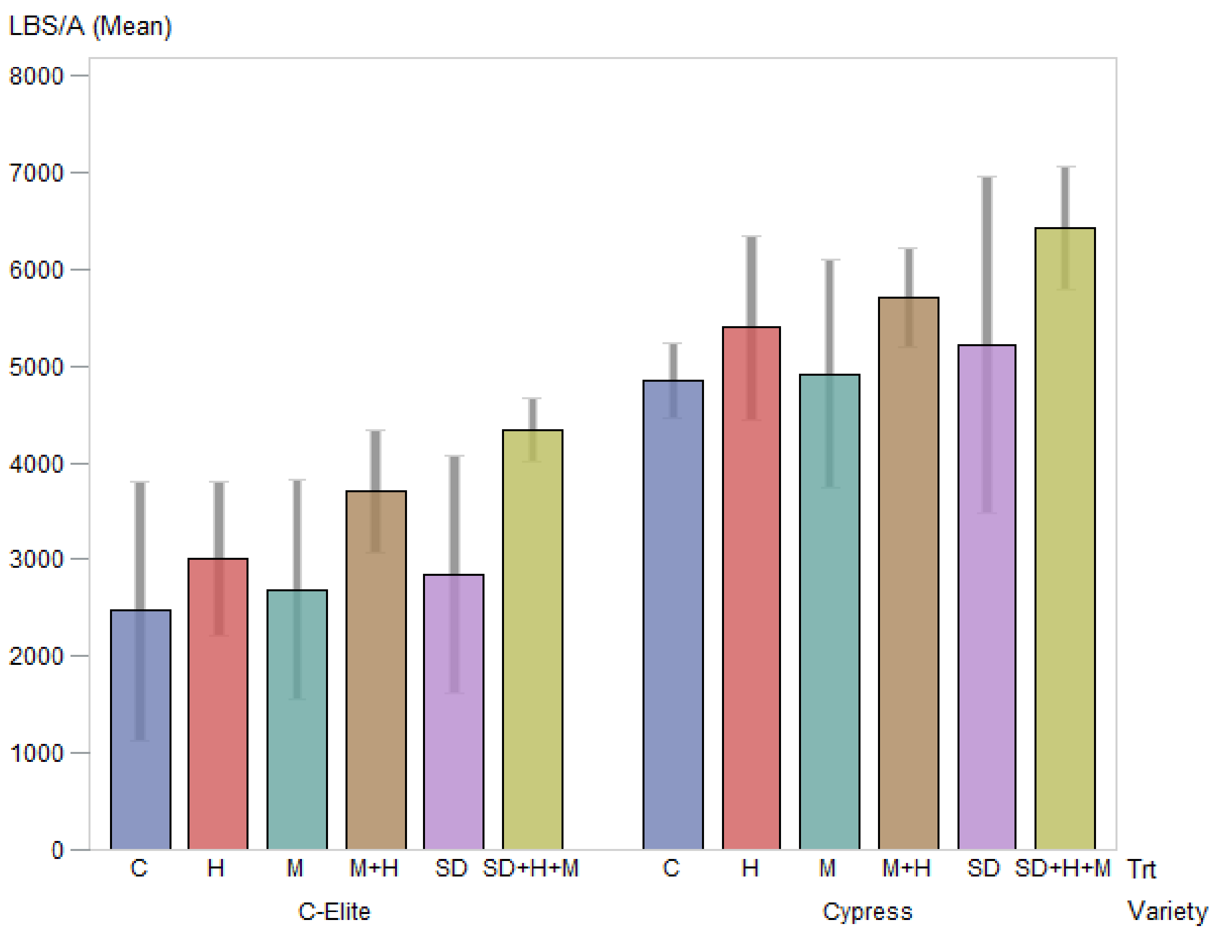
Project Approach: **Stress Mitigation Studies**

A 3-year study of split-set mitigation and stress management in beans and snap beans was conducted. This was modified in 2012 to look at overall stress reduction as well as split set mitigation.

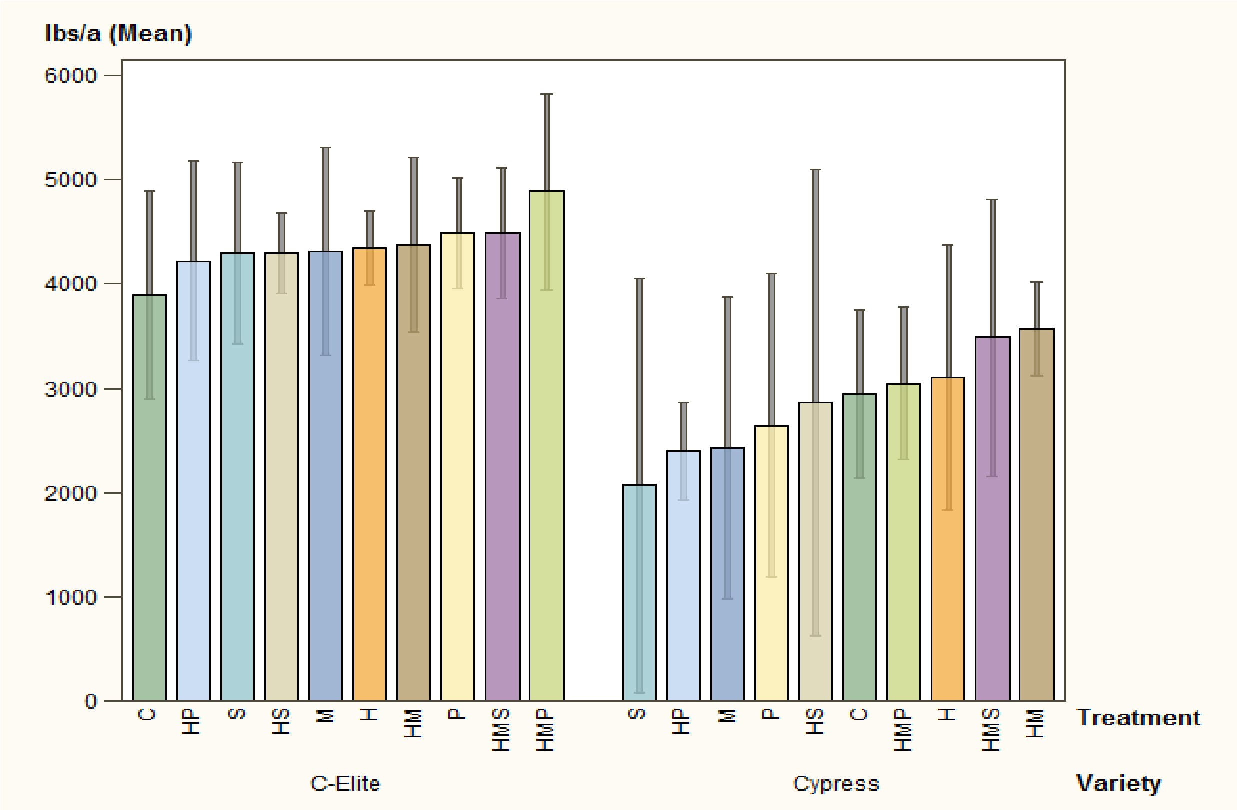
Two studies were conducted in lima bean in 2012. Treatments included use of particle films, cytokinin, and strobilurin fungicides, singly and in combinations under irrigation for stress reduction. Varieties were Cypress and C-Elite Select and there were 2 planting dates: early (heavy stress) and mid-season (moderate stress) plantings. Yield and yield component data was collected. Results showed a benefit from using particle films and combinations with particle film and strobilurin fungicides. 2012 was a very hot year with heat stress on the plants. See bar graph below. A 2013 study was also conducted in snap beans with no significant differences between treatments.

Three studies were conducted in lima bean in 2013. Treatments included use of particle films, cytokinin, an experimental growth regulator (photon) and strobilurin fungicides, singly and in combinations under irrigation and in dryland plantings for stress reduction. Varieties were Cypress, Meadow, and C-Elite Select. Yield and yield component data was collected. 2013 results showed no significant difference with the treatments; however there was a trend for increased yields where particle films were used. 2013 was a low stress year with abundant rainfall through the summer. The trial was repeated in 2014 with Cypress and C-Elite Select as the test varieties with irrigated and non-irrigated studies. Again, there were no differences between treatments in 2014 (2014 was also a low stress year). 2012 and 2013 results are shown below (C is the control). There was a trend over all years for increased yield with combined treatments with a particle film and strobilurin fungicide (with a cytokinin product in 2012 and 2013).

2012



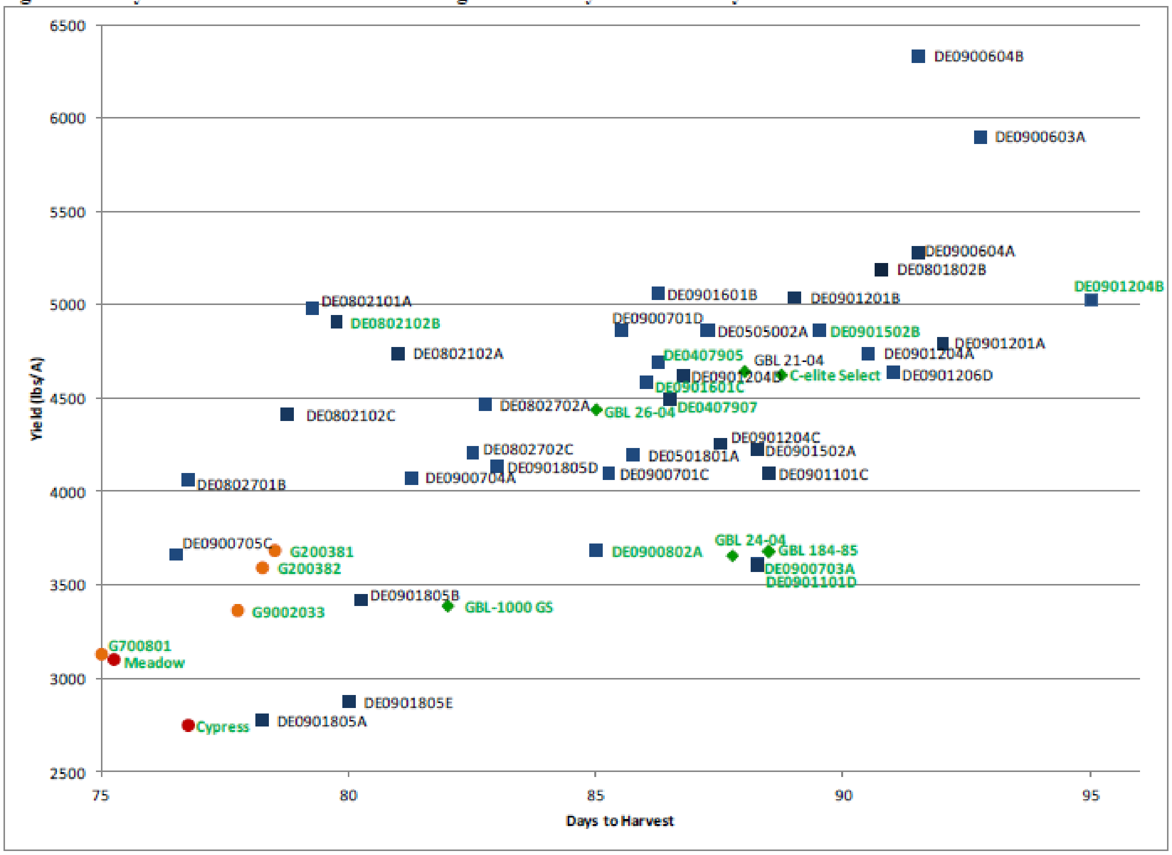
2013



Irrigation work is being done in cooperation with Agricultural Engineers at the University of Delaware. Again, no stress tolerant strains were available in enough volume to use in this work so the one trial with lima beans in 2012 used standard varieties. The 2013 trial was destroyed due to flooding and 2013 trial was destroyed due to deer damage. This work is presented in a separate report

Drought stress tolerant lines and heat stress tolerant lies from the UD lima bean breeding program were tested in separate studies in 2012-1014. Several lines performed better than the standard varieties tested against. Reports from this work are available at: http://extension.udel.edu/ag/vegetable-fruit-resources/vegetable-small-fruits-program/variety-trial-results/. An example graph from those trials is shown below.

Figure 2. Baby Lima Bean Varieties in the Irrigated Trial by Yield and Days to Harvest*



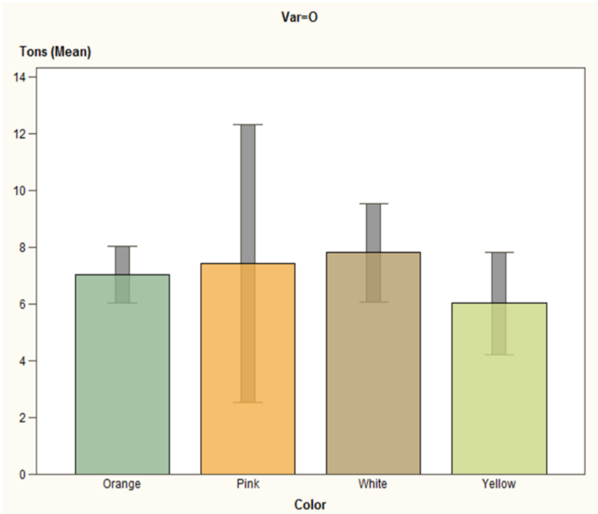
* Green-seeded varieties are indicated by green data point labels.

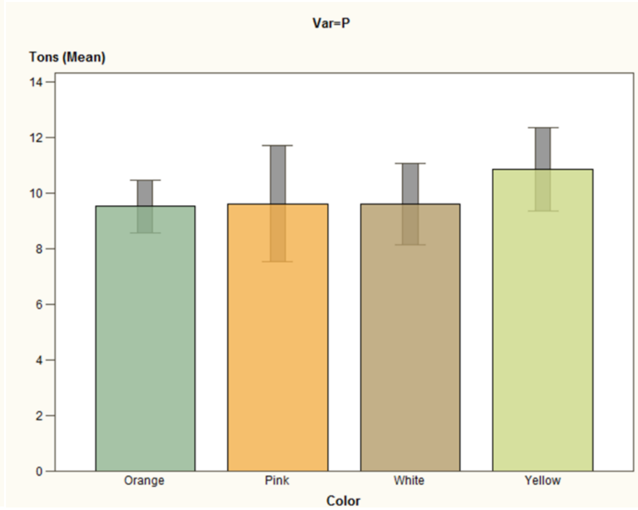
Nitrogen Fertilization in Processing Sweet Corn

In 2012, two studies were conducted using variable rate nitrogen in processing sweet corn and target fertilization at recommended and higher than recommended rates. In both studies, yields in higher rates were not significantly different from the lowest rate (155 lbs. N per acre) and the variable rate performed as well as the other fixed rates. In 2013, two studies were conducted in processing sweet corn and target fertilization at recommended and higher than recommended rates. Greenseeker NDVI data was collected on treatments. Optimum N in both studies was between 150 and 175 lbs/a. See tables below. Varieties were Overland and Protégé.

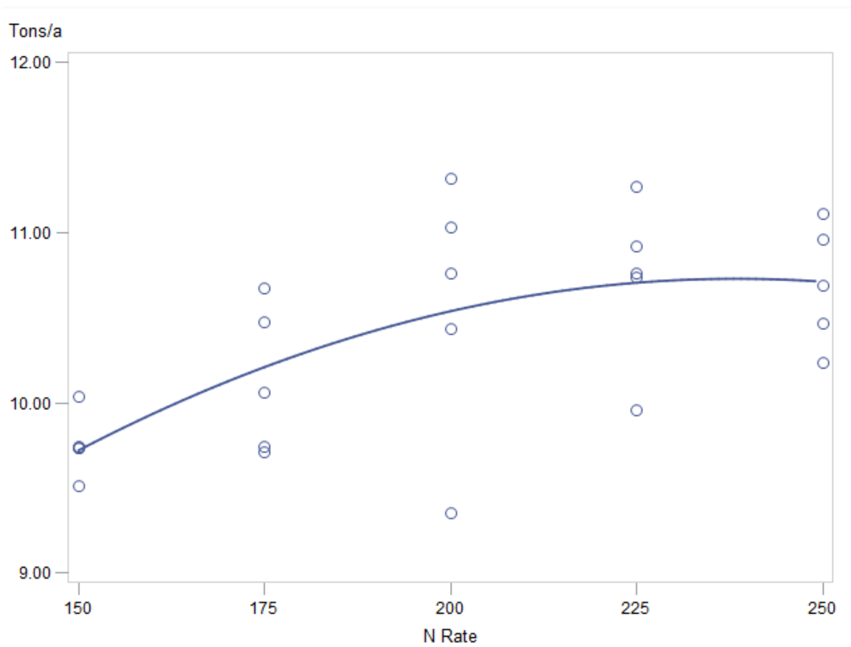
In 2014, four studies were conducted on N fertilization with target fertilization rates at recommended rates and above recommended rates (150, 175, 200, 225, and 250 lbs/a N). Optimum rates in 2014 were 175-200 lbs of N per acre. Varieties were Overland and Protégé. In addition a population and N rate study was done with GSS2952P See tables below.

2012 Studies

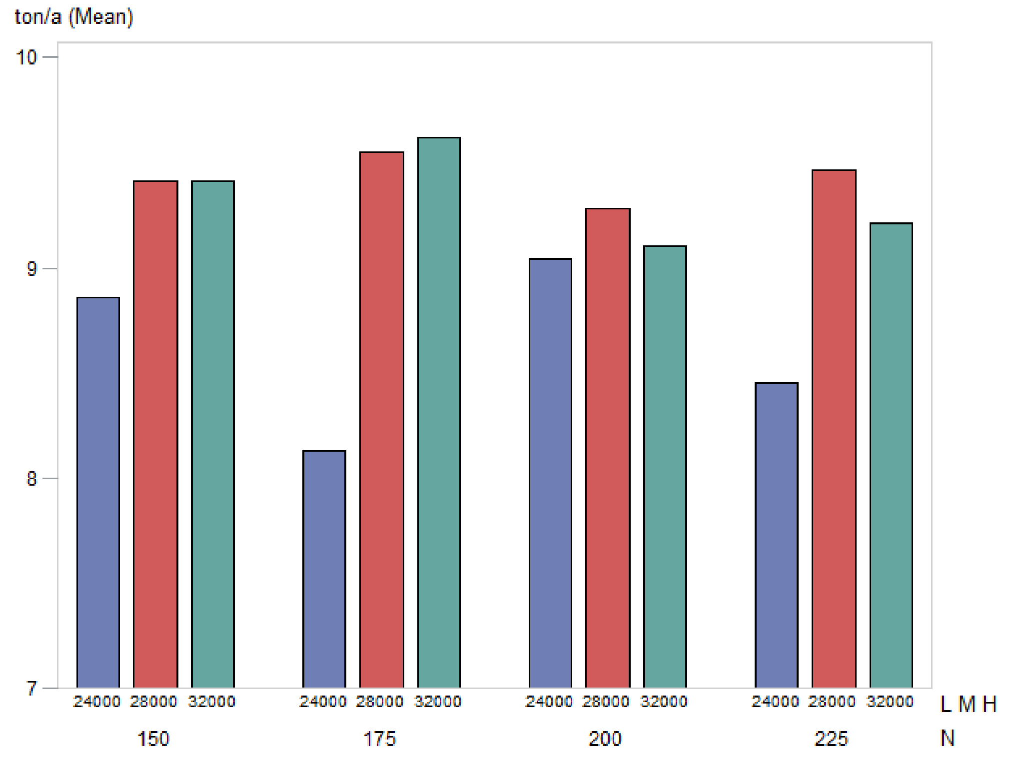




2014 N fall study



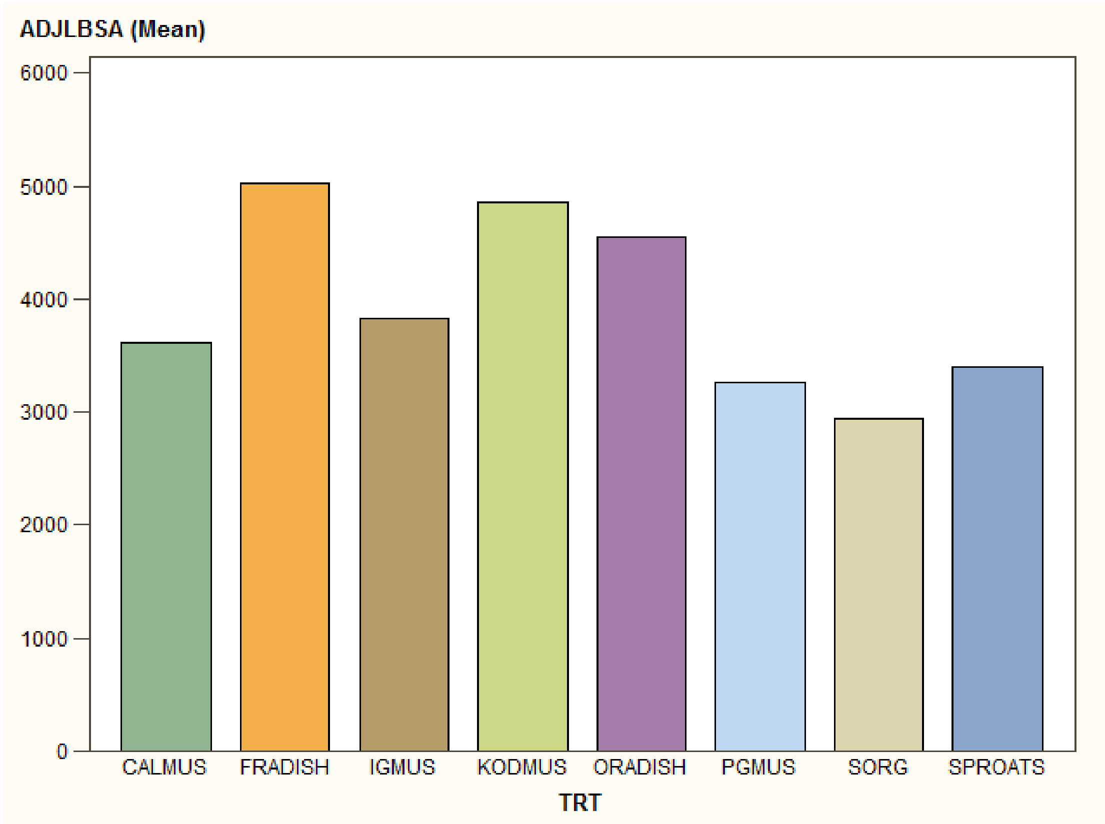
2014 Population and N study



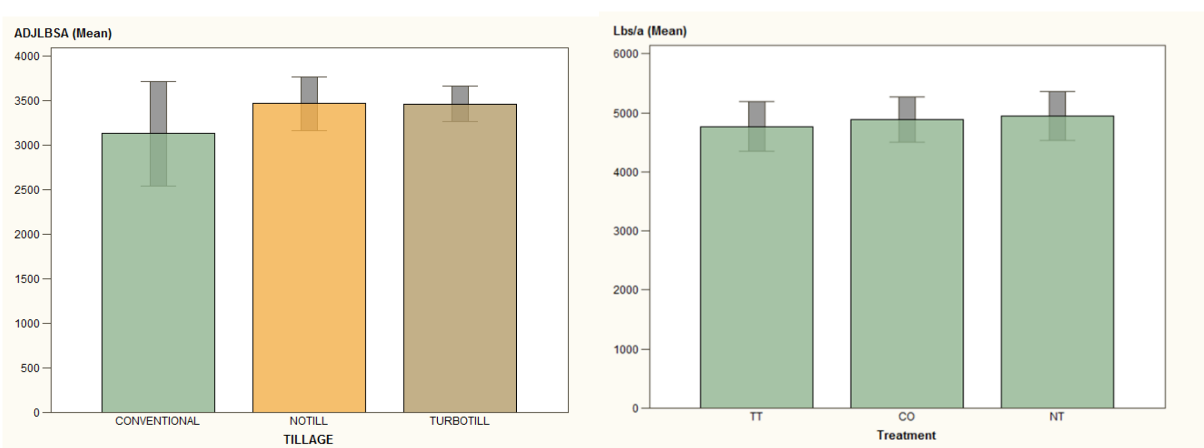
Pea Tillage Studies With Radish and Mustard Cover Crops for Compaction Mitigation

In 2012, a small plot trial with eight winter killed cover crop species was conducted and peas were no-tilled into the plots in March. Cover crop biomass, pea stand, pea yield and pea quality data was taken. In addition, a large plot pea study was conducted in a field where forage radishes were planted. The trial had three treatments – conventional tillage, vertical tillage, and no-till in the spring following the forage radish cover. Stand, biomass, yield, and quality data was collected. Results showed that forage radish, oilseed radish, and Kodiak mustard treatments provided the best yields. Tillage studies showed that no-till peas into winter killed forage radish may be a viable option for growers and had better yields than conventional treatments.

Yields of Peas After Mustard and Radish Cover Crops No-till 2012

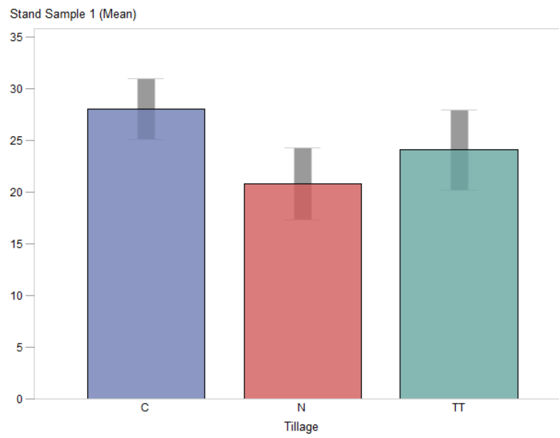


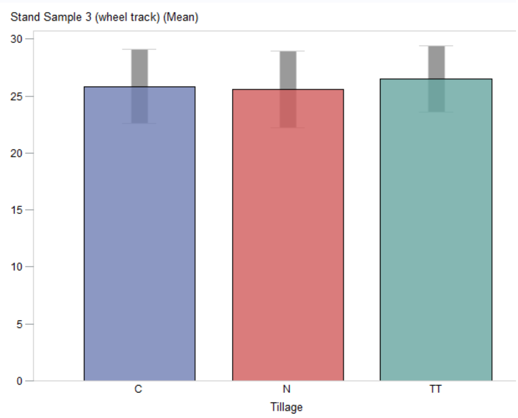
Yield of Peas by Tillage Treatment 2012 (left) and 2013 (right)



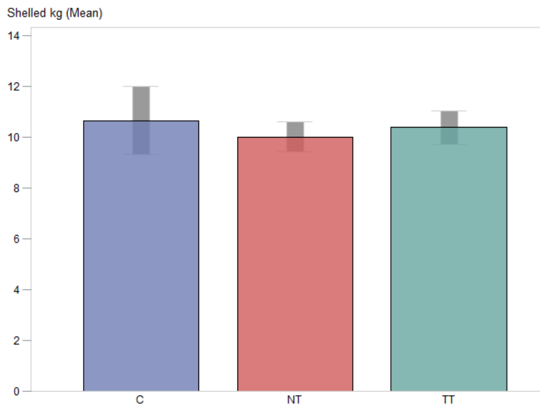
In 2013 the trials were repeated. A small plot trial with eight winter killed cover crop species was conducted and peas were no-tilled into the plots in March. Cover crop biomass, pea stand, pea yield and pea quality data was taken. In addition, a large plot pea study was conducted in a field where forage radishes were planted. The trial had three treatments – conventional tillage, vertical tillage, and no-till in the spring following the forage radish cover. Stand, biomass, yield, and quality data was collected. In 2014 there was an additional trial with peas planted after winter killed forage radish. These studies also showed that peas were successfully no-till planted after forage radish. However, stand counts were lower in both no-till and vertical tillage plots and compaction was lower in conventional plots. See graphs that follow.

Pea stands by tillage type and cover crop in middles and in row tracks 2014

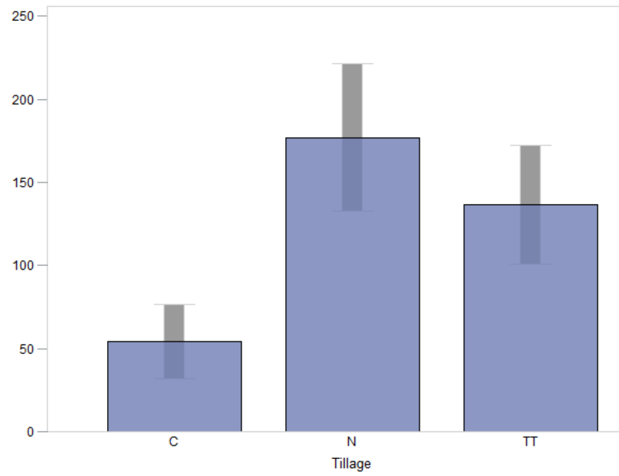




Pea yields by tillage and cover crop 2014



Compaction in peas by tillage (psi force) at 4” 2014



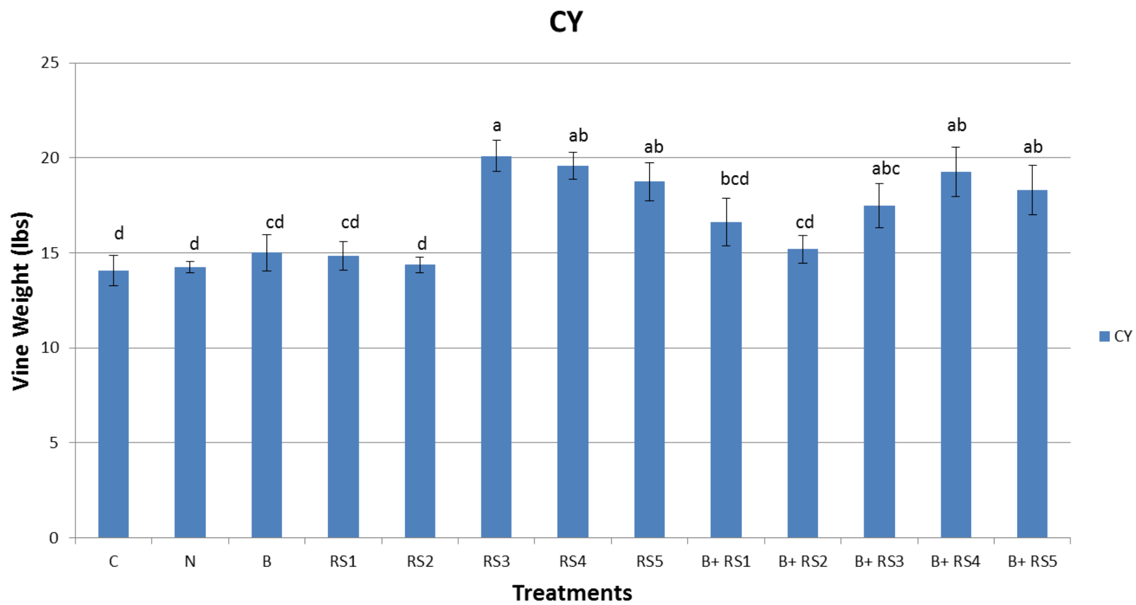
Improved Rhizobium Inoculants for Lima Beans

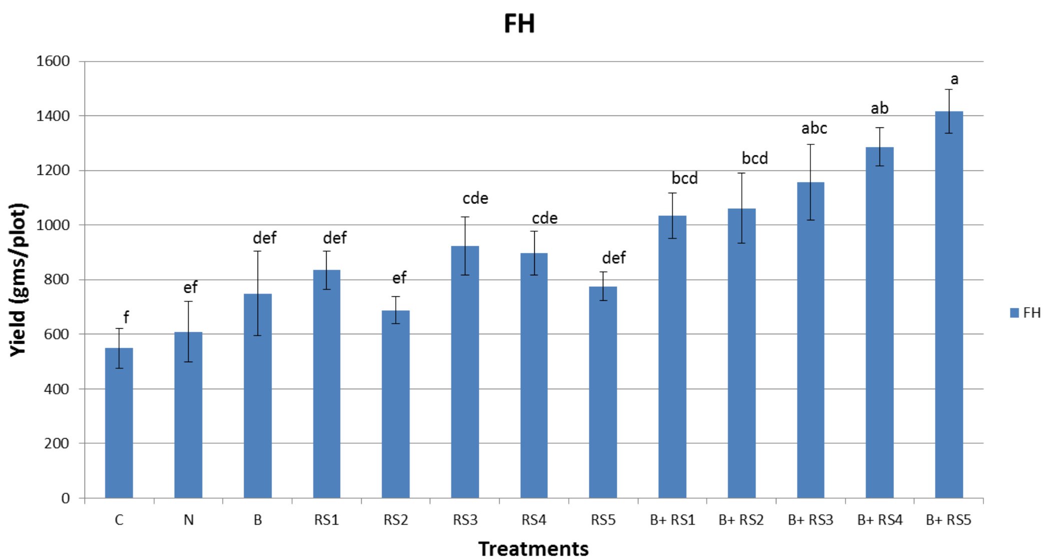
Soil samples were taken from the field in November, 2012 from areas where beans had grown. These were used to isolate different Rhizobium strains in the laboratory. Tests were conducted to identify superior strains during 2012. However, work was not completed until after field planting season was over. Therefore, field trials could not be conducted in 2012. It was decided to concentrate research on lima bean inoculants.

In 2013 a greenhouse study was conducted looking at over 40 Rhizobium strains in baby and Fordhook lima beans under no nitrogen conditions. From these studies, 15 strains were selected, based on their effects on plant growth in the greenhouse for field testing in 2013 on both baby and Fordhook lima beans in small plots. Plant weight, seed yield, and maturity data was collected for each strain. From the field research, four strains were identified for further testing with baby limas and three strains were identified for further testing in Fordhook lima beans.

In 2014, a field study with strains selected from 2013 trials was conducted. Seed were inoculated with the improved rhizobium strains with or without a beneficial bacteria using two baby lima bean varieties and one Fordhook variety. Results are presented below. Note that one strain in particular, RS3 is showing good promise.

Rhizobium inoculant RS3 showing promise on baby limas and Fordhook varieties 2014 field trial.

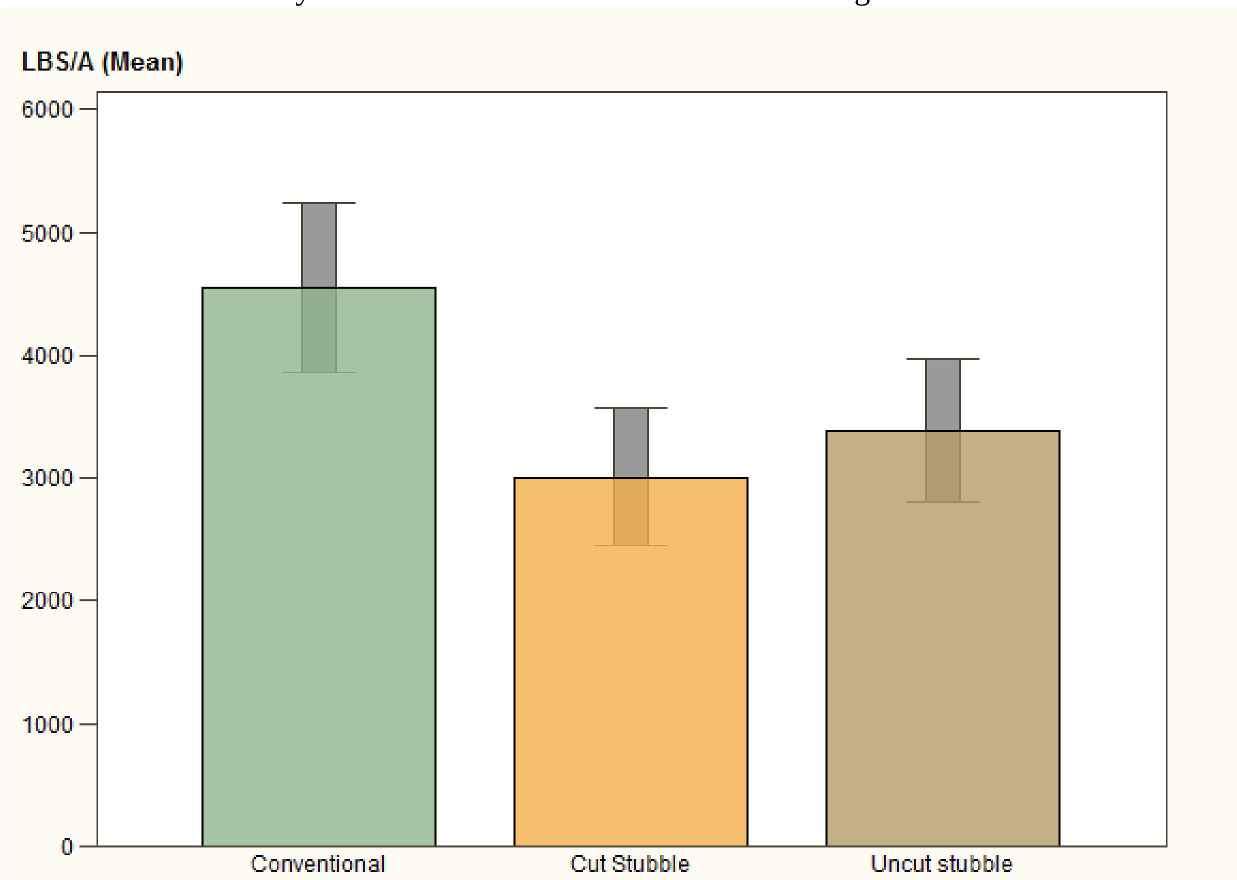




Tillage Trials

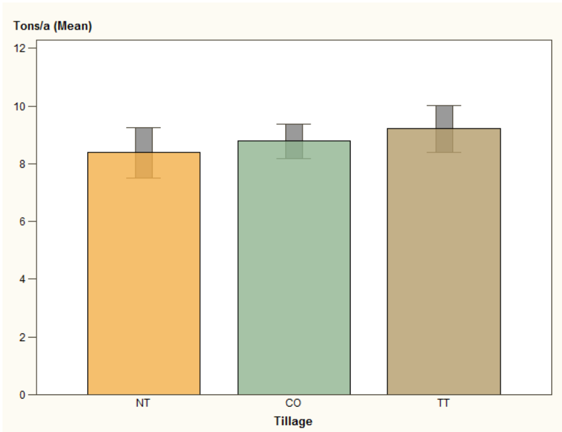
Studies were initiated in 2012 looking at tillage practices in processing vegetables. This included a pea study planted into winter killed forage radish under three tillage practices, a processing sweet corn study planted after winter cover crops under three tillage practices, and a lima bean study planted after small grain under 3 tillage practices. Results indicated that peas are successfully no-tilled, early processing sweet corn performed best under conventional tillage and lima beans performed best under conventional tillage.

Lima bean yields under different tillage treatments 2012

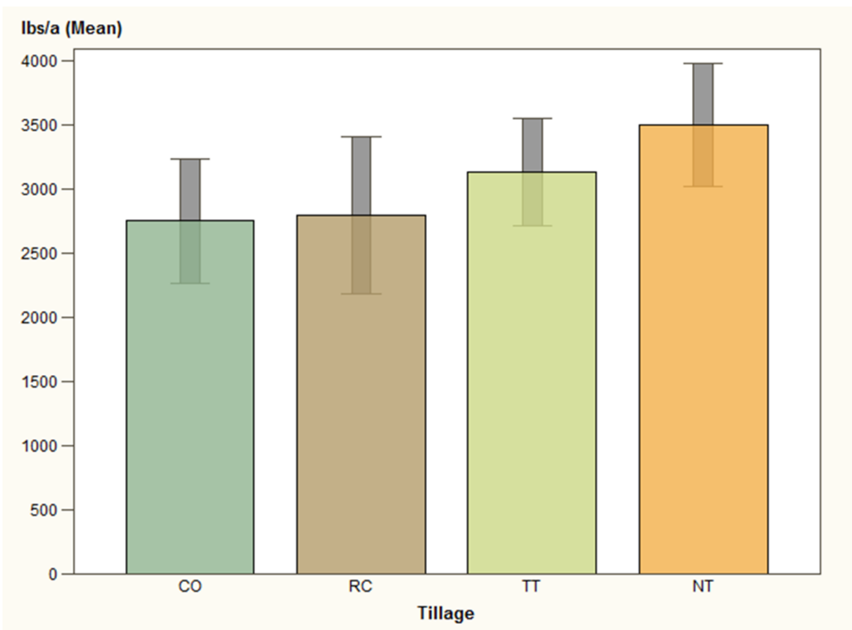


Studies were conducted in 2013 and included pea, sweet corn, and snap bean studies planted into winter killed forage radish under three tillage practices and lima bean, snap bean, and sweet corn planted after wheat under 4 tillage practices – no-till, strip till, vertical tillage, and conventional tillage. In these studies there was no yield reduction with no-till in peas, sweet corn or snap beans in spring studies planted after forage radish. Summer studies planted after wheat showed no difference between tillage treatments in any crop.

Sweet corn tillage treatments after forage radish cover crop spring 2013.

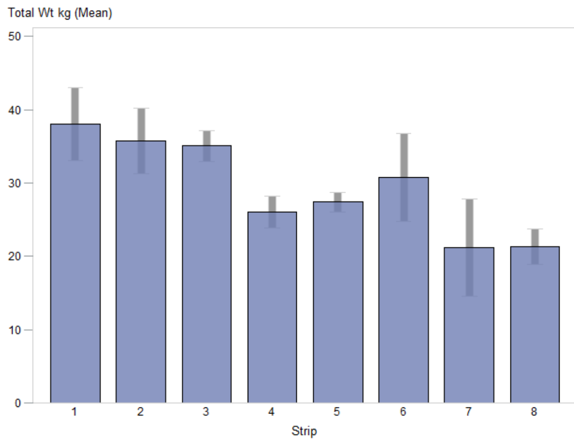


Lima bean yield by tillage treatment after wheat 2013.



Studies were conducted in 2014 and included pea, sweet corn, and snap bean studies planted into winter killed forage radish under three tillage practices and lima bean, snap bean, and sweet corn planted after wheat under 4 tillage practices – no-till, strip till, vertical tillage, and conventional tillage. In these studies there was no yield reduction with no-till in peas (see pea section above) or snap beans in spring studies planted after forage radish. Summer studies planted after wheat showed reduced yields in lima beans in no-till and vertical tillage treatments. In both spring and fall studies, no-till plots had significantly lower yields in the crops studied. Vertical tillage and strip tillage performed similarly to conventional tillage.

Spring snap bean tillage trials 2014. Strips 4 and 7 are no-till. Conventional tillage are strips 3 and 6.



Regrowth Cropping Studies

A regrowth cropping study was conducted in 2012 using Cypress and C-Elite Select lima bean varieties. Included in these trials were stress reduction treatments (particle films, cytokinin application, strobilurin fungicide application) for the May planting. Cypress plots were mechanically harvested that last week in July and yield data collected. C-elite was not harvested due to pod losses in the extreme heat of July. The Cypress trial continued with regrowth treatments including three nitrogen treatments with and without strobilurin fungicide. These plots were harvested the second week in October. Preliminary results show that the Cypress variety has more heat tolerance than C-Elite Select and can be successfully recropped. Nitrogen addition was critical for obtaining high yields in the regrowth. In addition, a cooperating farmer regrowth cropped lima beans on his farm. Yields in the regrowth cropping were over 5000 lbs in the high yielding treatments.

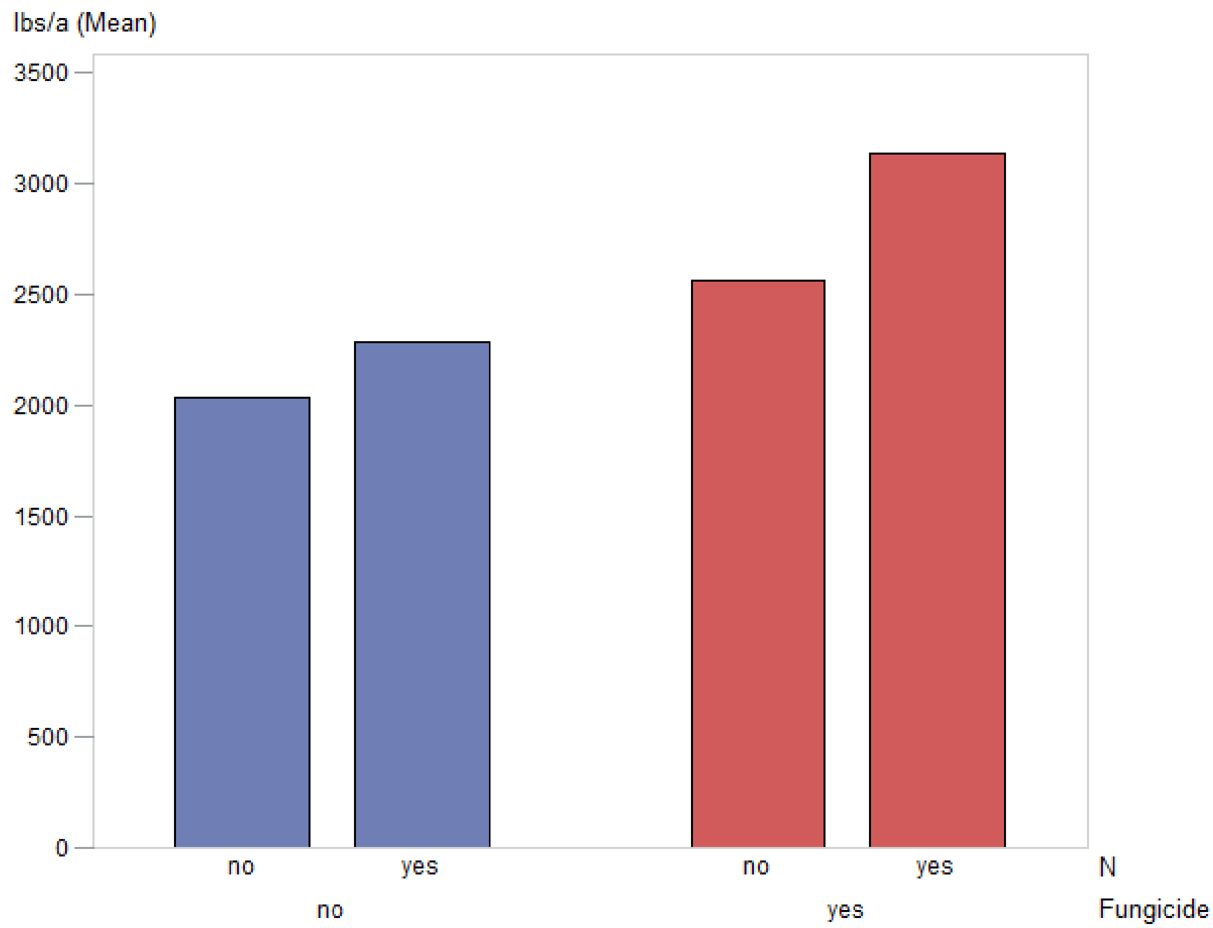
Regrowth cropping study in 2014.

	Nrate			Total
	0	40	80	
	lbs/a	lbs/a	lbs/a	lbs/a
	Average	Average	Average	Average
F+	3546.50	5127.07	5663.02	4747.21
F-	3439.79	5003.76	5335.76	4555.77
Total	3493.15	5065.42	5499.39	4651.49

The 2013 trial was not successful due to severe pod loss and weed pressure. Cooperator plots were also damaged by flooding and were not conducted.

In 2014 regrowth cropping studies were done with the varieties Meadow and M-15. Spring yields in the Meadow plots averaged 1200 lbs/a with some samples over 1600 lbs/a. M-15 had much lower spring yields. Fall crops were hampered by the cool growing season. M-15 did not mature in time to harvest. Meadow yields are shown below with or without additional fungicide and with or without additional nitrogen. Highest yields were obtained with both fungicide and nitrogen. Total yields with spring and fall combined in high plots approached 4500 lbs/a.

Regrowth cropping yields in 2014 for the variety Meadow.



Goals and Outcomes Achieved: Goal 1. Stress mitigation in beans.

A 3-year study of split-set mitigation and stress management in lima beans and snap beans will be conducted. This research will include evaluation of heat tolerant varieties for Delaware adaptation, evaluation of newly developed stabile cytokinin hormone products to reduce split set, the use of strobilurin fungicides to reduce split set, and irrigation programs to reduce split set (and combinations). Advanced breeding materials from the lima bean breeding program at UD will be preferentially tested.

Stress mitigation studies were conducted in all three years but emphasis was placed on lima beans because of their importance to the Delaware vegetable industry. The use of spray-on materials (particle films, cytokinin and other growth regulators, strobilurin fungicides) was inconclusive with some indication of potential benefits. Additional research in stressful years will be needed.

Tests of advanced breeding materials has identified several breeding lines with potential heat tolerance. These are being further advanced and tested. Backcross breeding will be necessary for a number of these lines to get acceptable seed color.

Goal 2. Nitrogen rate optimization in processing sweet corn.

A 2-year study of nitrogen fertilization and processing sweet corn variety interaction under optimum irrigation conditions and a 3-year study (in cooperation with the Nutrient Management research program) on variable rate N side-dressing in processing sweet corn using sensor technology.

Nitrogen studies showed that current recommended rates for processing sweet corn are adequate under most years and growing conditions (150-175 lbs/a N) for 7-9 ton yields. In a high yielding year (2014) where yields were over 10 tons per acre, there is evidence that 200 lbs per acre may be needed for highest economic yields. This information has led to readjusting current recommendations for processing sweet corn in the region.

Only limited work was possible with variable rate nitrogen applications to sweet corn due to equipment constraints. However, the 2 studies that were conducted showed that this technology is promising and therefore further study is needed..

Goal 3. Compaction mitigation and improved pea performance using no-till and cover crops with an emphasis on forage radishes.

A 3-year study of compaction mitigation in peas comparing tillage tools (such as vertical till devices) with winter killed cover crops (such as tillage radish) under conventional, limited tillage, and no-till conditions will be conducted.

Studies showed that peas can be successfully no-tilled into forage radish and mustard cover crops without a yield decrease or change in maturity. However, there was also no advantage in yields. Compaction was not reduced in no-till plots when compared to no-till into forage radish with the exception of wheel tracks. An advantage to the no-till pea/forage radish winter killed forage crop was the reduced trips across the field and reduced field tracking. This work gave enough evidence to recommend the practice to growers on a trial basis.

Goal 4. Develop improved Rhizobium strains for beans.

Three years of testing of improved Rhizobium inoculants for lima beans and snap beans to provide N (in cooperation with researchers in the Plant and Soil Science Department at UD) and other bacterial root inoculants that have the potential to confer stress and disease resistance will be conducted.

Due to constraints with cooperating researchers, only lima beans were included in this goal. This goal was partially achieved. Potential rhizobium strains with improved N-fixing ability were identified and tested. Several strains were further tested and at least one of these strains shows great promise. More research will be needed to advance the improved strain and the next step will be larger scale strip trials in commercial settings.

Goal 5. Assess the viability of no-till, strip-till, and vertical tillage for major processing vegetables in Delaware.

A 3-year study of no-till and strip till for peas, lima beans, snap beans, and sweet corn. The research focus will be on winter killed cover crops for pea no-till and early snap beans no-till and strip-till; no-till lima and snap beans into small grain stubble (including trash contamination at harvest), and no-till and strip till sweet corn into winter annual legume residue.

Studies showed that both no-till and strip-till are viable systems for producing peas with radish or mustard cover crops. Sweet corn and snap bean are more variable following forage radish due to the potential for stand losses when using no-till. Vertical tillage performed equal to the conventional tillage in these trials and can be recommended. For no-till after small grain, results were also more variable. Sweet corn performed equally well in row cleaner and vertical tillage methods but not consistently in no-till. Lima beans cannot be recommended to be no-tilled at this time due to potential yield losses as shown in 2 of 3 years of the studies.

Goal 6. Assess the potential for regrowth cropping of lima beans.

A 3-year study of the potential for re-growth cropping of lima beans will be conducted

Regrowth cropping was shown to be potentially viable but there are several issues that need to be resolved. First, early yields are below economical in some years due to flower and pod drop to heat. A more heat tolerant early variety will be necessary to make this system work well. June and July are also the most susceptible time to losses due to stinkbugs and lygus bugs so additional scouting and pest control will be necessary for the early crop. In addition, weed control in the first crop is critical or the regrowth crop will not perform properly. The studies showed the benefits of added nitrogen and fungicides.

Beneficiaries: Information from these studies has been presented to the processing vegetable industry representing Delaware and the Eastern Shore counties of Maryland. Reports were presented in 2012, 2013, and 2014 at the Fruit and Vegetable Growers Association of Delaware annual meetings at Delaware Agricultural week, University of Delaware Vegetable Program field days each August in the same years, pea twilight meetings in 2012 and 2014, a lima bean forum in 2012, and a vegetable growers meetings in Maryland in 2012 and 2013. In addition, information has also been presented in the same years at the Mid-Atlantic Vegetable Growers conference. This information has reached over 150 processing growers, all major crop advisors working in processing vegetables in the region and all processing company representatives. This represents over 30,000 acres of production. In addition, this information has been presented throughout the Mid-Atlantic, from Maryland to New York, reaching over 500 growers, advisors, and processing company personnel.

Lessons Learned: Overall, the project was a success with many outcomes that will help the industry in future decision making. Tillage studies identified processing vegetable crops where reduced tillage is feasible. Nitrogen studies led to changing current recommendations in processing sweet corn. Stress mitigation studies showed that resources should be concentrated on the breeding side with lima beans. Promising research with inoculants will be progressing due to this project. Regrowth cropping studies showed potential with additional research. Much of this project was conducted at one site and needs to be replicated in grower's fields which should be the next step.

Contact Person: Dr. Gordon C. Johnson, Direct Phone: (302) 856-2585 ext. 590, Email: gcjohn@udel.edu

Project Title: Development of Molecular Markers for Downy Mildew Resistance Race F in Lima Bean

Project Summary: The major objectives of this project were to: 1) use genotyping-by-sequencing (GBS) to identify markers associated with resistance to *P. phaseoli* and 2) set-up a marker assisted-screening system for the lima bean breeding program at the University of Delaware's Carvel Research and Education Center in Georgetown, Del. Pertaining to objective 1, this project (in association with other, related efforts) led to the development of molecular techniques and bioinformatics tools for GBS, which were used for analysis of lima bean resistance to race F of *P. phaseoli*. This project is intended to leverage modern tools for lima bean breeding while also advancing our understanding of natural variation in lima bean. Mapping a major resistance gene is a good starting point because of the simple inheritance and relevance to lima bean production. However, modern tools are not simply transferred across systems and this project sought to overcome some basic hurdles associated with technology transfer. Ultimately, this project is designed to develop of a GBS platform for the molecular genetic analysis in lima bean as well as a set of rapidly scoreable marker assays for targeted introgression of race F resistance. In a separate project, these markers are now being evaluated further to determine how well they can predict the presence of race F resistance in germplasm unrelated to the population they were discovered in.

Single nucleotide polymorphism (SNP) loci and validated SNP assays for marker-assisted selection were discovered in this project. Using an F_2 population segregating for race F resistance (Bridgeton x B2C; related parental lines), GBS-bulk segregant analysis (GBS-BSA) led to the identification of 12 of 146 pass-filter SNPs that exhibited a signature of phenotypic association. From among these 12 candidate SNPs, seven were converted into KASP assays useful for screening large numbers of individuals, and all ~200 individuals of the F_2 population were genotyped at each of these marker loci. Six of the markers were linked to each other and significantly associated with race F resistance. The race F resistance locus was mapped in between markers ~4.5 cM apart, providing the intended outcome for the objective. Pertaining to objective 2, we have acquired necessary equipment and supplies to extract DNA from lima bean tissue for marker assisted selection at Georgetown. Renovations of the laboratory facility at Georgetown have interfered with lab setup. Renovations are expected to be complete in early 2015, at which time we will setup for DNA extraction in the laboratory space currently occupied by the poultry diagnostic clinic.

Project Approach: Genotyping-by-sequencing methods were developed or improved and applied to identify markers associated with qualitative resistance to downy mildew of lima bean. An F_2 population of ~200 individuals derived from a cross between parental lines Bridgeton and B2C (related by three generations of backcrossing) was previously scored for resistance to race F of *P. phaseoli*. This population and data were used to discover and phenotypically associate SNP markers by BSA and linkage mapping. GBS-BSA was performed first, using two separate bulks of DNA from 140 resistant plants and 61 susceptible plants. Two independently formed replicates of the resistant and susceptible bulks along with two replicates of the parental lines were sequenced on an Illumina HiSeq using a custom GBS protocol (Wisser et al., unpublished).

Goals and Outcomes Achieved: This project aided in increasing capacity for variant discovery, marker assay development, and identification of marker-trait associations for lima bean. Six SNP loci were found to be associated with race F resistance of *P. Phaseoli*, and assays developed for them can be used for screening lima bean germplasm and introgressing resistance into susceptible lima bean lines. The linkage map (section pertaining to the locus of interest, race F resistance) and a list of the primers used for the KASP assay are shown in Figure 1 and Table 1.

Figure 1. Linkage region containing six SNP markers (vertical line along x-axis in inner panel of plot) associated with resistance to downy mildew of lima bean. Linkage distance between nearest flanking markers indicated inside panel of plot.

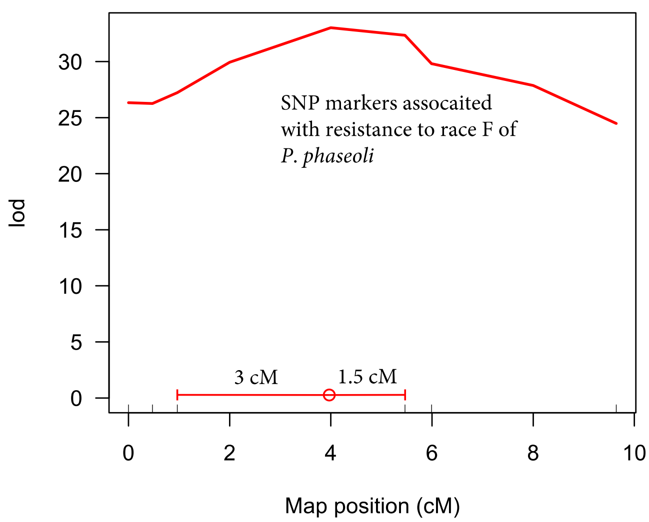


Table 1. Information on SNP markers from Figure 1.

assay_name	cM	LOD
20_1335858_56	0.00	26.3
fam	GAAGGTGACCAAGTTCATGCTTCTGAGTGGTTCTTTGTCTTC*A[1]	
hex	GAAGGTCGGAGTCAACGGATTTCTGAGTGGTTCTTTGTCTTC*C	
common	TTGCAAACGTGAAAAATGAGA	
24_389862_28	0.47	26.3
fam	GAAGGTGACCAAGTTCATGCTCCTCTGTAGTTTCTGATTGACAAAC*A	
hex	GAAGGTCGGAGTCAACGGATTCCTCTGTAGTTTCTGATTGACAAAC*G	
common	CCTGATGATCCAAGGAAAG	
20_1930486_22	0.96	27.2
fam	GAAGGTGACCAAGTTCATGCTTACTTTTTGTATCTCAGTATG*C	
hex	GAAGGTCGGAGTCAACGGATTTACTTTTTGTATCTCAGTATG*T	
common	GAACCTTAGAGAGGTCCCA	
24_923176_25	5.47	32.3
fam	GAAGGTGACCAAGTTCATGCTCAAGCCAGTCAATCAAACTCTC*C	
hex	GAAGGTCGGAGTCAACGGATTCAAGCCAGTCAATCAAACTCTC*T	
common	TGTGCTGTTTTGAGACTCTCTTG	
20_4047244_39	5.99	29.8

fam	GAAGGTGACCAAGTTCATGCTGATATCACAAATACCTTCATTATC*A	
hex	GAAGGTCGGAGTCAACGGATTGATATCACAAATACCTTCATTATC*G	
common	CTATTAAACTTGATTTAGAGGGGC	
20_5008519_72	9.64	24.5
fam	GAAGGTGACCAAGTTCATGCTATGCGTTTTCGCATGTCC*G	
hex	GAAGGTCGGAGTCAACGGATTATGCGTTTTCGCATGTCC*A	
common	CCGGTGCATATCTCTCATCC	

[1]Asterik indicates phosphorothioate bond (may not be required)

The second objective of this project was to set up a system by which the lima bean breeding program can use marker assisted selection for downy mildew resistance breeding, and eventually other traits as markers are developed. We have acquired necessary equipment and supplies to extract DNA from lima bean tissue for marker assisted selection at Georgetown. Renovations of the laboratory facility at Georgetown have interfered with lab setup. Renovations are expected to be complete in early 2015, at which time we will setup for DNA extraction in the laboratory space currently occupied by the poultry diagnostic clinic.

Lessons Learned

Although this project achieved the desired outcome, further work is needed to improve GBS-based variant discovery in genomes without a reference, like lima bean; Only approximately 10% of putative variants identified in this project could be leveraged for further analysis. Modifications to the bioinformatic analysis pipeline developed here (in conjunction with other projects) are under discussion.

Beneficiaries: Fifty growers DE and MD and 4 Vegetable Processors growing lima bean on 15-20,000 acres in the Mid-Atlantic Region will benefit directly from this work. In 2009, approximately fifty Delaware farms contracted with regional processors to grow lima beans (an additional thirty growers are located in nearby counties on the Eastern Shore of Maryland.) The Oomycete *Phytophthora phaseoli*, which causes downy mildew, is the most epidemic pathogen of this important vegetable crop (Davidson et al. 2002).

Contact Person: Dr. Thomas A. Evans, (302) 831-1066 direct, tomevans@udel.edu

Project Title: Improving Yields from Early-Planted Supersweet Processing Sweet Corn

Project Summary: An average of 6,500 acres of processing sweet corn were planted in Delaware each year from 2008 to 2012. Additional acreage is planted on the Eastern Shore of Maryland. Regional vegetable processors have begun using supersweet processing sweet corn varieties for the entire seasen, even in early plantings. Supersweet varieties produce a higher quality final product; however the seed is not as vigorous as the conventional sugary and sugary enhanced varieties. The recommended production practice is not to plant supersweet varieties until the soil temperature reaches 65°F. In the past, processors planted sugary and sugary enhanced varieties in the first several weeks of the season, and waited until late April or early May to plant supersweets. Now, supersweet varieties are routinely planted starting in mid-April.

One issue that can arise with any early-planted sweet corn, and even more so with supersweet varieties, is poor stand establishment. In such cases the grower and processor must then decide if the field is worth taking to yield, or if it should be abandoned/replanted. Some processing sweet corn varieties can produce sizable second ears and may be able to compensate for a certain degree of stand loss. One goal of this project was to compare the yield of several commercial supersweet processing sweet corn varieties at different plant populations in order to determine what percent of stand may be lost and still attain an acceptable yield.

In 2010 and 2011 the University of Delaware Vegetable Program conducted processing sweet corn variety trials supported by a Specialty Crop Block. One finding from the 2010 early-planted supersweet trial was that some supersweet varieties had good emergence, even with an April 12 planting date. In 2011, a variety emergence study was planted on April 7. In this study some supersweet varieties had 90% emergence, while others produced much lower stands.

Several factors seem to be involved in the vigor of supersweet corn under cold, early-season planting conditions, particularly genetics (variety) and seed quality (which can be affected by age and storage conditions). There is anecdotal evidence that some varieties are less affected by poor storage than others. Another goal of this project was to determine if there are supersweet varieties that are better suited to early planting and more tolerant of poor storage conditions.

Project Approach:

Field Experiments

Field studies to test the impact of stand reduction on processing sweet corn yield were conducted in 2012 and 2013. The varieties tested and the stand reduction treatments were chosen in consultation with the fieldmen from the three vegetable processors that contract sweet corn on the Delmarva Peninsula.

The 2012 experiments were designed to determine the effects of stand reduction (different plant population densities) on processing sweet corn yield, and see if there is interaction effect between variety and stand reduction. Some varieties were expected to yield compensate for stand loss more than others. Various yield components were measured with the goal of better understanding how plants are compensating for yield loss (for example, are plants producing larger ears, or are they producing more ears per plant).

Two experiments were conducted in 2012, both contained the same treatments and the same parameters were measured. They were planted in different fields on different dates.
Yield was measured in two ways (weight of ears in the husk, weight of cut corn). Also measured were: plant characteristics (plant height, ear height), quality and maturity indicators (percent moisture) and yield components (ear length, ear weight, ear diameter, kernel depth, ears per plant). Measurement of cut corn yield was accomplished in partnership with a regional processor, S.E.W. Friel, through the use of their mechanical corn cutter.

The 2013 field experiments were designed to determine the effect of stand reduction, gap size and the interaction between these two factors on processing sweet corn yield. Two varieties were tested at populations of 100, 80, 60 and 40 percent of standard planting density with reduced stands achieved by thinning plants evenly or adding random gaps of 1-plant, 2-plants, 4-plants or 8-plants (approximately 18, 24, 45, or 81 inches respectively). Two experiments were conducted in 2013, both contained the same treatments and the same parameters were measured. They were planted in different fields on different dates. The parameters measured were the same as those described above for 2012.

Results from the 2012 experiments indicated that for some varieties, plant populations reduced to 60% of the standard planting population did not show significant yield loss. In other varieties, yield loss was significant at 60% stand reduction. The processor fieldmen have stated that these results are in line with observations they have made in the field, but did not have experimental data to corroborate. Results from the 2013 experiments again showed that some varieties can maintain yield at 60% stand reduction or more, but gap-size did not significantly affect yield, even when gaps were nearly seven feet long.

Germination Tests
In July 2012, twenty-five seed samples of supersweet processing sweet corn varieties from the 2010, 2011 and 2012 processing corn trials was subjected to the cold germination test and a germination test under ideal conditions. Results of these tests suggest that some varieties may have more cold tolerance than others. Also, some varieties had much better vigor in old seed samples than others did. While most of the seed samples from 2010 had 65% germination or less, two varieties had almost 100% germination under cold and ideal conditions. With seed of the five varieties from the 2012 field experiments we set up a test to evaluate different seed storage conditions. The germination tests for this experiment were completed in summer 2013. Results of these tests indicate that stored seed of some varieties germinated better under cold conditions than others. (Stored seed of all varieties germinated well under ideal conditions.) Also, seed stored in the two locations climate controlled to ~70°F germinated better under cold conditions than seed stored in an unheated shed or in a refrigerator.

Outreach and Distribution of Results
The results from the above experiments were presented to growers, processor fieldmen and crop consultants at the Fruit and Vegetable Growers Association of Delaware Annual Educational Meetings in January 2013 and January 2014. Recommendations based on the 2012 experiments were given in an article for the Weekly Crop Update

(http://extension.udel.edu/weeklycropupdate/?p=5323) and thereby distributed to the publication's 400+ subscribers.

Results were shared with regional Extension workers and Horticulture professionals at the Mid-Atlantic Vegetable Workers Conference in November 2013 and at the Northeast Region of the American Society for Horticultural Science meeting in January 2014.

A video presentation of the field portion of this research was created and distributed in January 2014 https://www.youtube.com/watch?v=Pzl43M6Eh10.

Goals and Outcomes Achieved:

Goal: Generate research based recommendations for processing sweet corn growers and fieldmen regarding: variety selection, seed storage conditions and yield under reduced stands.

Outcome Achieved: The research conducted as a part of this project has produced valuable information that growers and processors are using to make decisions in situations where sweet corn stand reduction has occurred. Extension personnel are also using this information to make recommendations in situations of stand reduction. One unexpected outcome of the research is that growers and processors began using a higher planting population for one of the varieties tested in the 2012 and 2013 trials which seems to produce a higher yield at a higher plant density than the other varieties tested. Based on experiments done as a part of this project, the recommendation to processors is to use the most recently produced and highest quality seed for early plantings, which are under the most stress. Use of carryover seed that has been stored for a year in climate controlled conditions can be successful, but is less risky in later plantings with warmer soil conditions. Processor fieldmen from the three companies that contract sweet corn in Delaware were interviewed in 2012 and 2013 and have repeatedly commented that the information from these trials has been very useful to them. One sweet corn seed company was intrigued by the results of these trials and is independently conducting similar experiments in other processing sweet corn producing regions.

Beneficiaries: The beneficiaries of this project are the approximately 75 farms growing sweet corn on Delmarva (DE: 33 and MD: 42) and the three regional sweet corn processors who are using the information generated through this project to decide what stand-reduced fields should be kept and which should be replanted. Since the results of this project indicate that most stand reduced fields will produce a yield equal or nearly equal to that of a full stand field, growers can almost always save the expenses of time and seed that would be expended in replanting a field. Recommendations for seed storage and variety selection for early plantings are helping to prevent occurrence of stand loss in early-planted sweet corn.

Lessons Learned: We were expecting to see some yield compensation in our reduced stand treatments, but we were surprised that for some varieties we did not see significant yield loss, even in stands that had been reduced to 40% of the standard planting populations. There was more weed growth in plots with very low stands, so stand reduction to this level is detrimental from a weed seed bank perspective, but, for some varieties, not from a yield perspective. The 2013 experiments were designed with feedback the processor fieldmen in mind: "You didn't see yield loss from stand loss, but you reduced stands evenly, and that's not usually what happens in the field." We were expecting to see some effect of gap size on yield in the experiments done in 2013 but we did not. This makes making a recommendation about whether to keep or replant a field with stand loss much easier. Gaps of up to 7 ft can be compensated for, so yield loss can be estimated simply by estimating stand loss.

As noted earlier in this report, one unexpected outcome of this project was the adoption of a higher planting population for a particular variety that responded to higher plant populations with higher yield in the 2012 trials. This variety had been trialed by processors on Delmarva but did not produce satisfactory yields – probably because it the standard planting density used here is too low for this particular variety.

No income was generated as a part of this project.

Contact Information: Emmalea Ernest, 302-856-7303, emmalea@udel.edu

Project Title: Grafting to Improve Watermelon Production and Yield

Project Summary: Interest in the practice of watermelon grafting has surged as the benefits of grafting, including improved watermelon plant vigor, greater stress tolerance, improved disease tolerance, improved fruit quality and longer holding ability become more widely known. The majority of watermelon production in Southeast Asia is grafted. However, the adoption of grafting in U.S. production has been slow. One obstacle to adoption of grafting has been the labor cost to produce transplants.

This study evaluated rootstocks for watermelon production and identified rootstocks that are well adapted to Delaware conditions and that have resistance to Fusarium diseases and root knot nematode. Grafting watermelons on adapted and resistant rootstocks provides growers with another tool to improve production. Although grafting will reduce susceptibility to Fusarium wilt, *Cucurbita* and *Lagenaria* spp. are susceptible to diseases caused by other Fusarium species. For example, Fusarium crown and foot rot are are present in Delaware, causing significant yield loss in susceptible species.

As Delmarva watermelon production industry moves towards grafting, it is important to evaluate local adaptability of candidate rootstock and to evaluate disease potential of crown and foot rot and other diseases on Cucurbitaceae spp.

Project Approach: Grafting and Rootstock Evaluations

2012 Studies

Grafting studies were conducted in both 2012 and 2013. 2012 studies were done with commonly used rootstocks (Strong Tosa, and Emphasis described above), other *Lagenaria* selections including common bottle gourd, hybrid bottle gourd, and accessions from the USDA collection); other *Cucurbita* accessions from the USDA collection; snake gourd (*Trichosanthes cucumerina*), and bitter gourd (*Momordica charantia*). Scions included 6 common triploid varieties and 2 common diploid pollinizer varieties. Grafting was done with a one cotyledon splice graft with rootstock severed at the soil line and then re-rooted in media. This method was successful with Strong Tosa and Emphasis but with only 55% success rate. There were no differences in grafting success by diploid or triploid varieties. USDA accessions varied considerably in their grafting success but none were better than the standards. Snake gourd and bitter gourd had poor grafting success.

Collection of isolates of Fusarium spp. and evaluation of their ability to cause disease on root stocks were conducted in 2012. Rootstock of ‘Strong Tosa’ (*Cucurbita maxima* × *C. moschata*) and ‘Emphasis’(*Lagenaria siceraria*) were planted at three mid-Atlantic locations to expand the University of Delaware Research and Education Center, Georgetown screening that was conducted in 2012. Rootstock were planted at University of Maryland’s Lower Eastern Shore Research and Education Center, Wye Research and Education Center, and Western Maryland Research and Education Center. Sixty fungal isolations were made from the roots of grafted plants, non-grafted rootstocks and from related cucurbit species. Thirty-six were selected for further study. Cultures were grown from a single spore (monoconidial isolates) and identified as putative Fusarium species.

2013 Studies

In spring of 2013, all grafts were done with Strong Tosa and Emphasis using the approach graft method with 8 different triploid varieties and 8 different pollinizers as scions. Success rate was 78%. All successful grafts in 2013 were planted in the field to confirm rootstock and scion susceptibility or resistance to Fusarium wilt. Root stocks and varieties performed as expected verifying that Strong Tosa and Emphasis are resistant to Fusarium wilt races present on the University of Delaware research farm and that all diploid pollinizers with the exception of Accomplice were susceptible the Fusarium wilt present (Figure 1). However, there were differences in severity noted with the triploid seedless varieties.

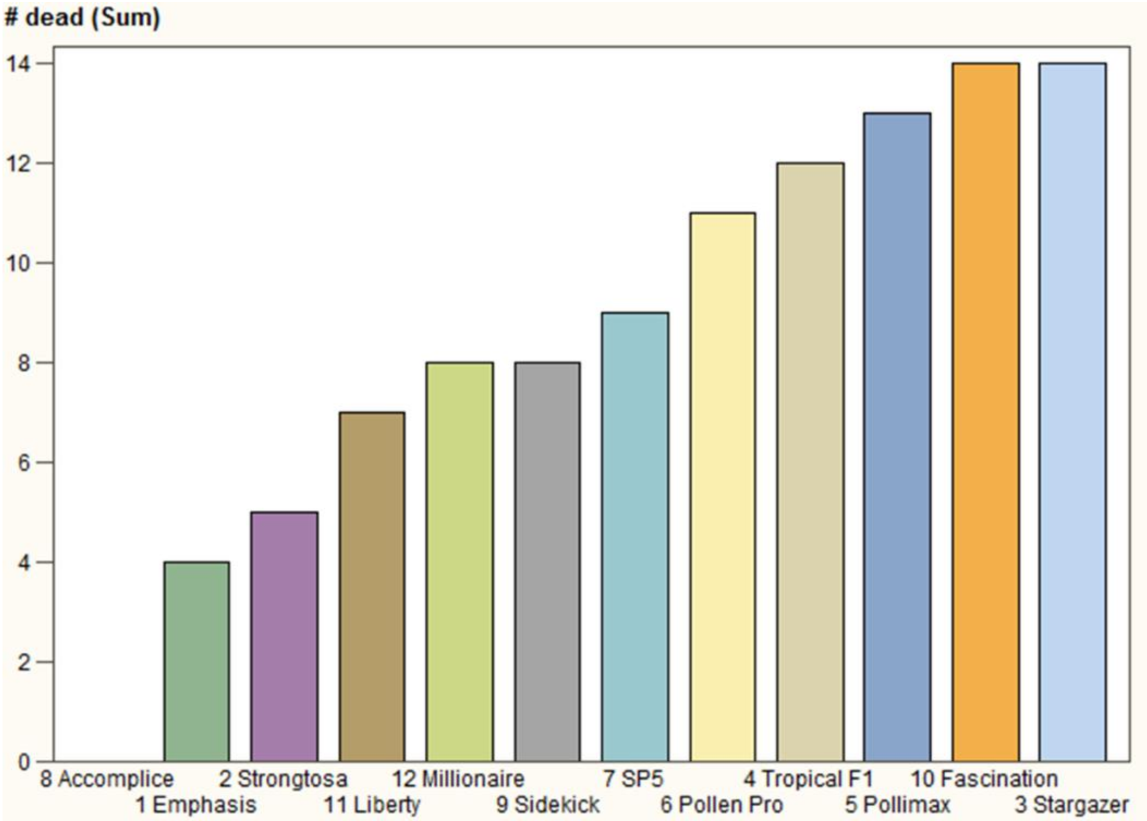
During June to September we evaluated grafted “StarGazer” for foliar disease. The trial was performed as a randomized complete block design with StarGazer scion that was grafted onto 1) Strong Tosa, 2) Emphasis, 3) Snake Gourd, 4) StarGazer (self graft), or 5) not grafted. Because the susceptibility of some of these combinations to Fusarium wilt and root knot nematode (RKN), we selected a field that was not infested with Fusarium wilt or RKN. Foliar disease was evaluated throughout the growing season. Survival of Emphasis grafted plants was low, often with only one plant in a plot. Therefore, the treatment was not included in our statistical evaluation. No differences in anthracnose, gummy stem blight or yield were observed in plots. We believe that because population size was low in plots (four plants per plot) that differences may have been observed at higher plant populations.

Grafted Watermelon Foliar disease Trial 2013

Rootstock	Anthracnose 23, July	AUDPC (gummy stem blight)	Yield/Plot (lbs.)
Strong Tosa…………………………………………	0.5	657	108
Snake Gourd………………………………………	2.3	742	138
Self-graft……………………………………………	1.3	762	87
Non-grafted Stargazer…………………………	2.3	757	66
P>F	0.2731	0.4093	0.1357

P values ≤ 0.05 indicate significant differences exist among treatments

Figure 1. Number of dead plants in rootstock, pollinizer, and triploid tests in 2013. University of Delaware Carvel Research and Education Center, Georgetown, DE.



2014 Studies

In 2014 a total of 18 different rootstocks were tested including bottle gourd, interspecific Cucurbita hybrids, and the wild watermelon selection from the USDA (*Citrullus lanatus var. citroides*). Entries were as follows:

- Harris Moran interspecific cross rootstocks: 1042, 1044, 1047, 1048, 1049, 1052, 1054, 1059, 1064, 1065
- Origene Seeds: BS-1 interspecific cross
- Syngenta Rootstocks: Carnivor interspecific cross, Strong Tosa interspecific cross,
- Emphasis bottle gourd
- Nunhems Rootstocks: Macis bottle gourd
- American Takii Rootstock – Marvel bottle gourd
- Highmark Seed Rootstock – Just interspecific cross
- USDA: RF318 Citrullus lanatus var. citroides wild watermelon rootstock

Grafting was done with a one cotyledon splice graft. The triploid scion was “Fascination”, pollinizer scion was “Accomplice” and Fascination was also self-grafted. Success rates were above 70% for all rootstocks. Side grafts were also attempted but success rate was under 20%. There were no differences in grafting success by rootstock in the trial.

Rootstocks were planted out for evaluation in a field with a history of Fusarium wilt both grafted and ungrafted. Rootstocks were evaluated for root health and vigor and crown health on a rating scale from 0-5 with 0 being given to plants that died within 4 weeks after planting, 1 for plants that died after 4 weeks, ratings 2-4 for root health (size of root system, root disease presence) and 5 being completely healthy and vigorous. For crown health ratings 2-4 were based on health of the crown area (disease present and extent) with 5 being completely healthy. Grafted plants were evaluated similarly. Results are presented in Figures 2, 3, and 4.

In Figure 2, rootstocks with root ratings of 5 included 1047, Just and Marvel. Rootstocks with root ratings greater than 4.5 included 1042, 1044, 1048, 1052, 1059, Carnivor, Emphasis, and RF318. It is interesting to note that the wild watermelon rating was high even though it has no reported resistance to Fusarium wilt. Rootstocks with ratings under 4 include 1049, 1054, 1064 and 1065.

Figure 2. Box plots of average root rating for rootstocks in 2014. University of Delaware Carvel Research and Education Center, Georgetown, DE. Diamonds represent the means.

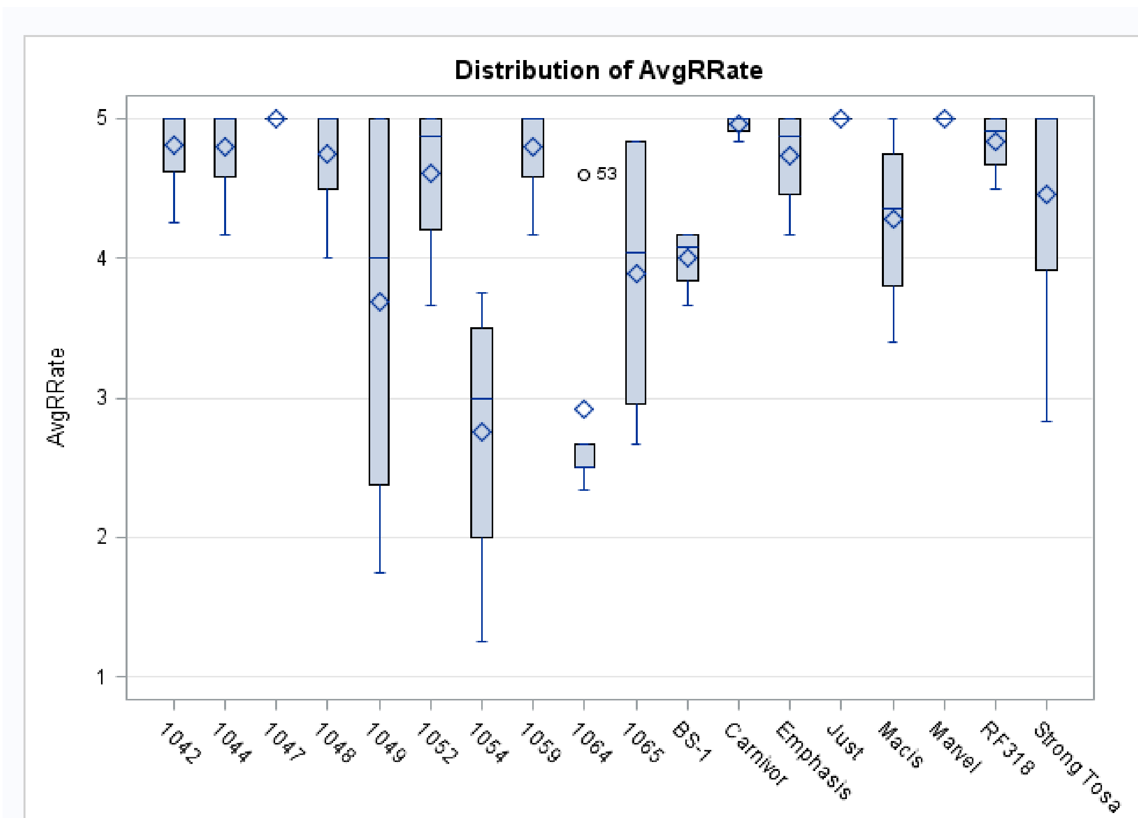
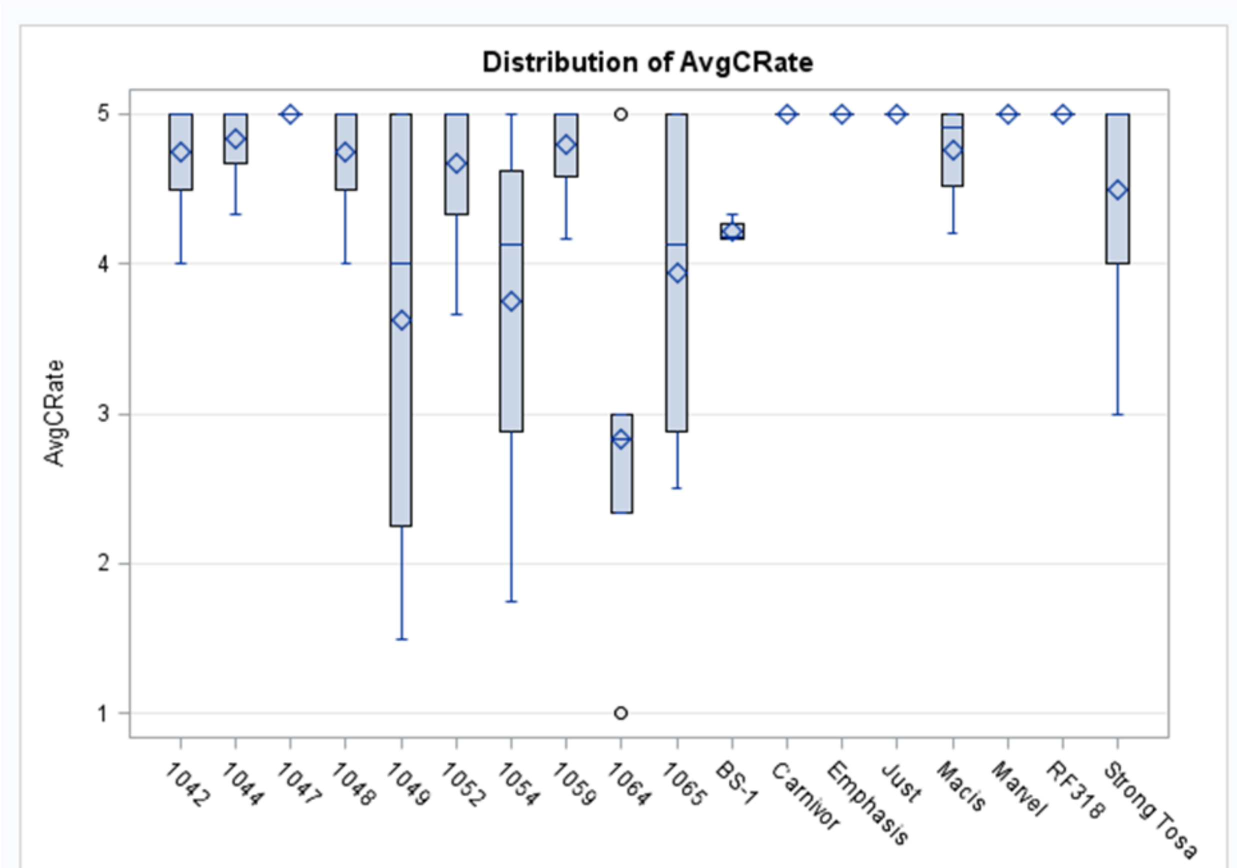
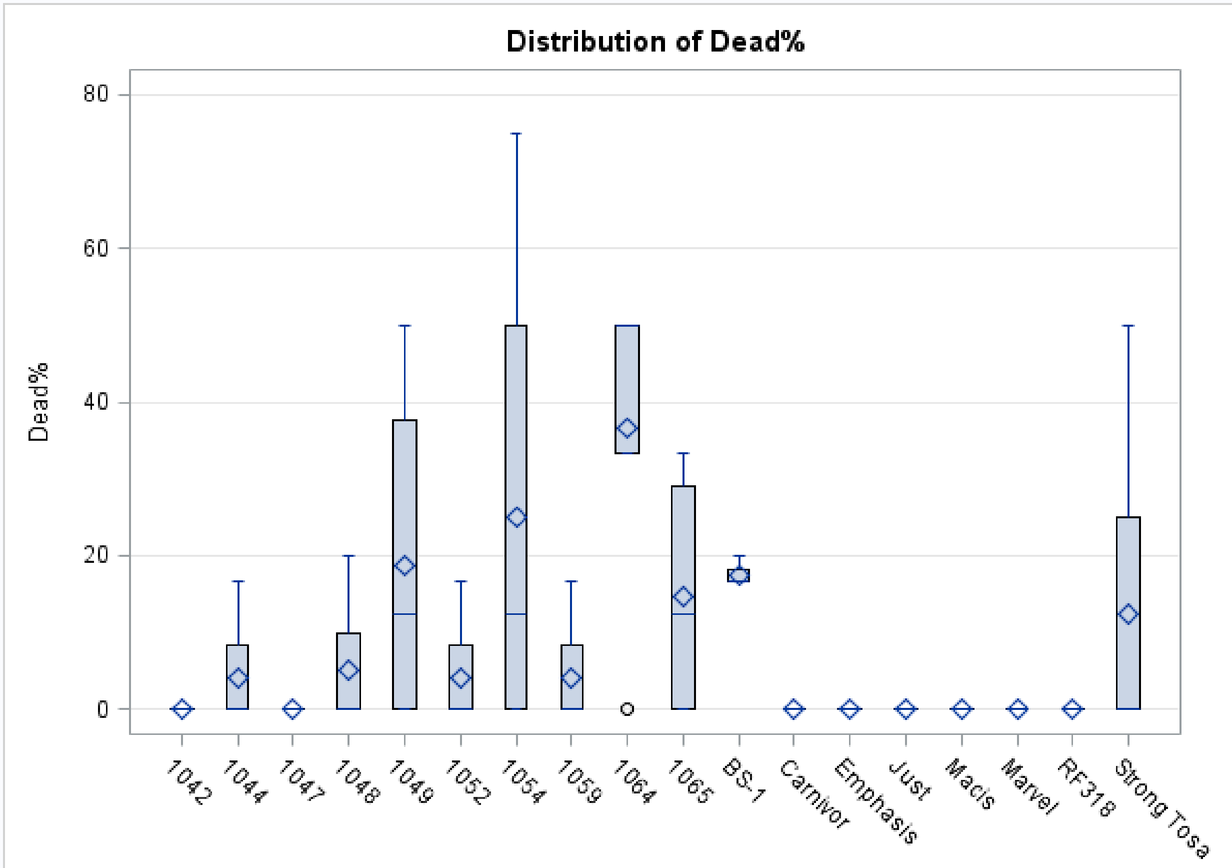


Figure 3. Box plots of average crown rating for rootstocks in 2014. University of Delaware Carvel Research and Education Center, Georgetown, DE. Diamonds represent the means.



In Figure 3, average crown ratings are presented. Rootstocks with a rating of 5 included 1047, Carnivor, Emphasis, Just, Marvel, and RF318. 1049 and 1054 had crown ratings under 4 and 1064 had a crown rating below 3. All others were above 4.

Figure 4. Box plots of dead plants found in plots for rootstocks in 2014. University of Delaware Carvel Research and Education Center, Georgetown, DE. Diamonds represent the means.



Dead plants in plots are presented in Figure 4. The rootstocks 1042, Carnivor, Emphasis, Just, Macis, Marvel, and RF318 had no dead plants. 1044, 1048, 1052, and 1059 were below 10% in mortality. The rootstocks with mortality over 20% were 1054 and 1064.

Evaluation of putative Fusarium isolates was conducted in winter 2013 and spring through summer 2014. Monoconidial cultures were obtained of individual Fusarium spp. cultured in 2012 and 2013. Root stock of Strong Tosa and Emphasis were inoculated using both the root dip and toothpick method. No cultures tested were pathogenic on either Strong Tosa or Emphasis.

Goals and Outcomes Achieved: We have identified new potential rootstocks that appear well-adapted to use in Delaware. Our outreach efforts have reached many watermelon growers over the project period.

Information on grafting and our work was presented at the 2012 and 2013 University of Delaware Agriculture Week and at the MarDel Watermelon Growers Meeting. We also presented information at two summer tours in 2012 and 2013. During 2012 and 2013, we estimate that 170 people have seen the presentations and demonstrations that resulted from this project.

An initial survey was conducted in 2012 to determine the baseline knowledge of grafting, with only 2 growers responding that they had used grafted plants. There was also a verbal survey at this year's MarDel Watermelon Grower's Meeting to gage the progress or our project. Approximately five operations indicated that they would use grafted plants if the price came down.

Paper surveys were not conducted during this project because the return rate of paper surveys is very low. Our survey in 2014 indicated that the adoption of this technology remains very low and has not increased by our goal of 100%. However our surveys also indicate the adoption is likely to significantly increase by 100% or more, if the price of the grafted plants is reduced.
Information on the 2013 trial was presented at the MarDel Watermelon Growers meeting with over 40 in attendance representing over 1500 acres of production. 2014 information will be presented at Delaware Agriculture Week in the Fruit and Vegetable Growers Association of Delaware annual meetings. In addition, a grafting workshop for crop advisors was held at the Mid-Atlantic Vegetable Growers Meeting in 2014.

Beneficiaries: Our beneficiaries are the watermelon growers who farm more than 2,700 acres of watermelons in Delaware with an estimated value of $11 million dollars. There are over 80 farms in Delaware that grow watermelons. There were an additional 2100 acres grown in nearby Eastern Shore of Maryland with a value of $7.5 million dollars on 75 farms.

Grafting and rootstock research has led to the identification of rootstocks with potential for use in Delaware. Adoption of grafted watermelons will be dependent on their availability in the future and cost versus benefits. New grafting techniques developed by the USDA and Clemson University need to be evaluated. No Fusarium isolates that were pathogenic to rootstocks were identified in the project period. Although this study cannot preclude that pathogenic Fusarium spp. to Strong Tosa and Emphasis exist in Delaware, the current inoculum level is likely low.

Lessons Learned: We were surprised that no pathogenic isolates of non-wilt fusaria were found. We know that this pathogenic group is present in Delaware. Additional surveys should continue to assess the threat of this pathogen on grafted watermelon. The positive experience is that many rootstock performed well in fields infested with the wilt form of Fusarium (F. oxysporum f. sp. niveum). This pathogen is present in most Delaware watermelon fields.

Contact Person: Kathryne Evert, 410-742-8788, keverts@umd.edu

Project Title: Delaware Farm to School Implementation Plan for 2012-2014

Project Summary: Many children are not consuming enough fruits and vegetables, a key component of a healthy diet. The United States Department of Agriculture (USDA) indicates that only two percent of children meet the USDA Food Pyramid serving recommendations. In addition, thirty-seven percent of Delaware children are overweight or obese. Almost nine in ten Delaware parents consider "not eating well – that is, eating too much junk food and not enough healthy foods"—to be a problem for Delaware's children and teens. At the same time, the economics of farming have become more challenging. Less than two percent of the U.S. population is involved in farming, and the federal Census Bureau has declared the number of farms "statistically insignificant."

Farm-to-School emerged in 2000 in response to the nutritional inadequacy of children's diets, the struggles faced by farmers, and a desire to increase students' access to fruits and vegetables by connecting them with fresh, local specialty crops. The Delaware Departments of Agriculture, Education, and Health and Human Services recognized the importance of FTS and established a FTS Advisory Committee in 2010 made up of representatives from the agriculture and education community. Delaware is now one of forty eight states with an operational FTS program. There is national support for FTS as well. President Obama continues to stress the importance of creating distribution systems that link small, local farmers to public schools who want more fresh fruits and vegetables. In fact, the U.S. Department of Agriculture just announced a new rule that encourages schools to bring in more "unprocessed locally grown and locally raised agricultural products" by allowing schools to give local providers preference when they bid for school food contracts.

The overall goal of this proposal is to increase local fruit and vegetables in Delaware public schools. This goal fits into the following objectives of the Delaware SCBG:

- to increase child knowledge and consumption of specialty crops; and
- to develop local and rural agricultural economies, and improve food access in underserved communities.

The strategy to meet this goal is to a.) develop a Delaware FTS Implementation Plan for 2012-2014 and b.) in conjunction with the Delaware FTS Advisory Board, ensure specific items in the plan are put into action. Key deliverables will include survey analysis of food service directors and Delaware farmers, website launch, networking events, procurement directory, press coverage, research on national models, and an evaluation model.

Project Approach:

- The Delaware Farm to School Advisory Board meet on a quarterly basis and is working to make Farm to School participants a more cohesive partnership.

- 2012 House of Delegates Meeting – Doug Davis was the keynote speaker for the 2012 House of Delegates meeting for the Delaware School Nutrition Association. He is the food service director for Burlington School District in Vermont. Doug has been recognized for his Farm to School efforts and has incorporated processing during the summer months so that local products can be utilized year-round in his District. He had an audience of over 275 cafeteria workers and Food Service Supervisors from

Delaware. Doug provided insight on Farm to School and sharing best practices utilized in his district.

- Procurement Directory – Completed by the Department of Agriculture the Procurement Directory is available on the Farm to School website. It includes the contact information for each Child Nutrition Supervisor, sorted by district, their delivery days and times, and the number of schools in their district. The growers section includes their contact information as well as a listing of their offerings. To date there are 13 growers but more are slowly being added.

- Farm to School Website – A website has been created and launched. It is housed on the Delaware Department of Agriculture website. The website features the Food for Thought videos from the 2007 SCBG, the Procurement Directory, Mission Statement, and Program Accomplishments (with links and photos) to date.

- Farm to School Event – The Delaware Farm to School Board presented during the Direct Marketing Sessions at the 2012 Ag Week. They provided refreshments to all attendees demonstrating menu items which can be found in school lunchrooms across Delaware. All 19 Child Nutrition Supervisors were in attendance.

- Watermelon Wednesday – Thirteen of the nineteen school districts participated in Watermelon Wednesday. Watermelon producers were partnered up with the school districts to hand out slices of watermelon to school children and to teach them the benefits of eating fresh watermelon.

- Meet your Farmer events – Several fruit and vegetable producers have visited Delaware schools. They bring in different fruits and vegetables to teach the benefits of healthy eating. This also helps the children identify different fruits and vegetables. They also provide samples to the children.

- 2013 Ag Week – the Delaware Farm to School Advisory Board had a table on Wednesday, January 16 at the 2013 Ag Week. This is the most attended day by fruit and vegetable producers. The Child Nutrition Supervisors handed out materials on what is a traditional school breakfast and lunch.

- 2013 Grower Summit –Child Nutrition Supervisors from all nineteen school districts attended this year's 5th Annual First Rate – First State grower summit. This summit is a great opportunity for our Child Nutrition Supervisors and Delaware fruit and vegetable growers to network.

- 2013 and 2014 National Farm to School Network's Annual Meeting – The Delaware Department of Agriculture was asked to send a representative "State Lead" to the National Farm to School Network Annual Meeting to learn about what some of the other states are doing with their Farm to School programs and to meet with the Mid-Atlantic Farm to School Regional Lead Agency. The Delaware Department of Agriculture paid all of the expenses for this trip and no grant money was used.

- Farm to School Brochure – The Farm to School Advisory Board has created and printed a tri-fold brochure outlining Delaware's Farm to School program. This brochure will be updated annually and will be available at all events that they attend.

- 2014 Ag Week – the Delaware Farm to School Advisory Board exhibited January 15-17 during Delaware's Annual Ag Week. Members of the Advisory Board sat on a Farm to School panel during a Direct Marketing Session titled "Making Valuable Connections".

- 2014 Delaware State Fair – The Farm to School Advisory Board exhibited for five days in the Commodities and Education building. They also held several presentations while exhibiting to promote Delaware's Farm to School program.

- 2014 First Rate-First State Growers Summit – Fourteen of our 19 school district sent their Child Nutrition Supervisor to attend the First Rate-First State Growers Summit. This was a great opportunity to meet with local fruit and vegetable producers that are looking to supply schools with fresh fruits and vegetables.

- Exhibitor Display – The Farm to School Advisory Board worked with the Delaware Department of Agriculture's Marketing Department to design and purchase a Farm to School display, table cloth, and marketing materials to use at future events.

- Project Survey – In October 2014 the final survey was sent to the School Nutrition Supervisors to evaluate the amount of fresh fruits and vegetables that are being consumed in Delaware schools.

G**oals and Outcomes Achieved:** The overall goal of this project was to increased local fruit and vegetables in Delaware public schools. The short-term measurable outcomes were that each of the deliverables outlined in the work plan are completed by the due date.

The long-term measurable outcome was that by 2014, there is a Farm to School Program in at least 10 school districts. This goal has been achieved and exceeded. On average Delaware has 14 school districts that participate in the Farm to School program and there have been several events where all 19 of our school districts have participated.

Project Survey – In October 2014 the final survey was sent to the School Nutrition Supervisors to evaluate the amount of fresh fruits and vegetables that are being consumed in Delaware schools. All 19 school districts have reported that they have participated to some degree in the Delaware Farm to School Program. Some of the produce the schools are purchasing from Delaware producers is strawberries, asparagus, broccoli, apples, sweet potatoes and watermelon. It appears that Delaware schools are spending approximately 8% of their food budget on local produce.

All of the deliverables outlined in our project have been completed. The development of the Delaware procurement database/directory on the Delaware farm to School website has been a very successful tool for our school districts. As the demand for fresh produce from our schools increases and the number of Delaware producers who participate in the Delaware Farm to School Program increases our database will be continually updated.

The total number of students affected depended on the school district and number of schools that participated. Over 1/3 or 43,000 of Delaware's public school students have participated in the Delaware Farm to School program.

Beneficiaries: Since Delaware is such a small state it has not been difficult to get a majority of the school districts to participate in the Farm to School Program. The overall goal of this project was to increase local fruit and vegetables in Delaware public schools. There are 19 public school districts in Delaware with 129,395 students. The long-term outcome of this proposal was to have a Farm to School project in at least 10 school districts by 2014.The Farm to School program's success has been noteworthy. There have been times when all 19 districts have participated in the Farm to School program. And on average there are 14 school districts that take part in Delaware's Farm to School Program.

The other beneficiaries of this Farm to School Implementation Plan have been Delaware producers. The producers that participate in Delaware's Farm to School project have an additional fresh market for their fresh fruits and vegetables as well as the valuable relationships that have been formed between the producers and school nutrition employees.

Lessons Learned: The way that the Delaware Farm to School by-laws are set up, members of the Advisory Board volunteer's only to sit on the board for 2 or 3 year terms. Since the MOU was signed, the advisory board has changed twice. The only permanent position is the liaison from the Delaware Department of Agriculture to the Farm to School Program, whose stated role in the by-ways is to schedule the meetings, and to take, transcribe and distribute the meeting minutes. However, it appears that the liaisons role has become much larger. The liaison has completed the work required in this grant project and has completed all the necessary reports. The liaison has created, designed, ordered, and printed all the marketing materials for the Farm to School project. After January 2015, the advisory board and the Secretary of Agriculture will sit down and discuss the by-laws and make the necessary changes to the liaisons role, most likely making the liaison the Delaware Farm to School Coordinator.

Contact Person: Jo-Ann Walston, Delaware Department of Agriculture, 302-698-4592, Jo-Ann.Walston@state.de.us